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EDITORIAL

The growing role of citizen science in monitoring environmental change – achieving a balance with government programs?[1]

The evidence is becoming clearer, day by day, that changes are occurring at the global level in weather, climate, the oceans, land use and population distribution, all of which have serious implications for natural ecosystems and their inhabitants, in Canada and beyond. At the same time, government (public service) programs in recent years involving long term monitoring of the Canadian environment have been drastically reduced. This has affected our ability to detect spatial and temporal changes in a range of indicators, thereby inhibiting the ability of policy and decision makers to respond in a timely way to environmental changes. For example, Canada's exemplary Environmental Monitoring and Assessment Network (EMAN) that initiated Nature Watch, a national citizen science monitoring program (www.ec.gc.ca), ceased operation in 2010; its last regional workshop was held in 2006. Many EMAN-linked programs, in and out of government, have either stopped due to loss of funding and staff, or are just struggling to survive. Although a change in the federal government may reverse the pattern and essential monitoring may eventually resume in earnest, valuable data and information for recent years have been lost forever.

This situation highlights the pivotal role of citizen science, particularly when it is directed at monitoring the various natural environments in Canada and in our region. Such activity by non-government organizations (NGOs) is no longer just a valued supplement to government sponsored programs; in many cases, it has replaced them. However, this situation raises some questions, to be pondered by members of NSIS and the broad environmental community– is this trend towards an enhanced role for citizen science good for the country? How reliable are data and information gathered by citizen groups? Where do such data reside? Who writes and reviews the various reports? Who curates and archives the data and information? How long can citizen

[1] This article celebrates the 40th Anniversary of the Halifax Field Naturalists, founded in 1975. A description of its activities, together with its excellent Newsletters, can be found at www.halifaxfieldnaturalists.ca .

groups continue and under what funding envelope (i.e., some monitoring, such as for water quality and chemicals in sediments and tissues, is very expensive)? If there is going to be greater reliance on citizen science, such fundamental questions demand credible answers!

The respected role of citizen-led science has been shown particularly well by programs such as the Christmas Bird Count across Canada and the USA, and in Nova Scotia with the Spring Peeper Count and the Kejimkujik Common Loon Survey. In Halifax, there is the monthly reporting of anecdotal observations of plants, wildlife, and habitats, as well as related talks, by the Halifax Field Naturalists (HFN); this society, affiliated with Nature Canada and Nature Nova Scotia, is celebrating its 40th anniversary in 2015, a truly remarkable achievement. Bird populations, a key indicator of general ecosystem health, are monitored by the Nova Scotia Bird Society. Both of these local groups keep records. Of a more general nature is the annual Clean Nova Scotia beach clean-up and recording of marine litter, the Clean Annapolis River Project water quality program in the Annapolis River watershed, water quality monitoring in the Sackville and Cornwallis River watersheds, and many others. Such programs produce much information and also play a vital role in public education and awareness. But they do have limitations, as they are run by volunteers and specific programs may be short-term. Although there are exceptions, the data collected rarely follow standard management protocols and are seldom if ever housed in a central location. Reports are often placed on group websites, but with little assurance of longevity, access, and security. Indeed, funding challenges often limit or stop these groups and their programs in midstream. In contrast to government (public service) science, there is no formal mandate other than public interest, volunteerism and commitment to a worthy cause to maintain many of these citizen led science programs.

Ironically, despite such disadvantages, the importance of citizen-led science programs has been widely recognized, partly because many government-led and legally mandated programs have been reduced or eliminated. Our premise is that in an affluent country like Canada, with its continental and global environmental responsibilities, we need a balance between such citizen science programs, especially those monitoring aspects of the environment, and programs established and run by government. They are both needed. We believe that our challenge at present is to return to this balance.

A significant number of federal science and monitoring programs have been eliminated since 2011-2012 (e.g., the Arctic ozone monitoring program, the Experimental Lakes Area Program, ecotoxicology of pesticides related to marine open-water aquaculture sites) or continue with severe underfunding (e.g., the Gulf of Maine Council's, Gulfwatch contaminant monitoring program). Furthermore, whole research programs associated with understanding and mitigating the effects of chemicals in aquatic environments have ceased (e.g., the Department of Fisheries and Oceans, environmental chemistry and aquatic toxicology program; many similar programs in Environment Canada). At the same time, NGOs struggle for project funding and universities seldom become involved in environmental monitoring (with some marked exceptions, such as the Ocean Tracking Network program at Dalhousie University, the St John River studies at the Canada Rivers Institute, UNB-Saint John and the Community Conservation Research Network at Saint Mary's University, Halifax). The evidence points to too little long term monitoring of Canada's many ecosystems, a legislated mandate of government.

Despite the many good examples of citizen science across the Maritimes, the frequent lack of support for their organizations, combined with the cutbacks of government (both federal and provincial), do not bode well for understanding the current and future consequences of environmental threats in Canada and in the Maritimes. Public debate is needed around this issue. The NSIS, members of relevant NGOs, government departments at all levels, and the universities should get together to discuss the best ways to monitor natural ecosystems in our Region, and provide cogent arguments to bolster the long-term viability of NGOs and to counteract the troubling trends of cutbacks in public service programs. We need to identify how citizen science and government science, supported by research in the universities, can work together, as well as interact with policymakers, for a better future in a changing environment.

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REFLECTIONS ON TIME AND PLACE: THE NOVA SCOTIAN INSTITUTE OF SCIENCE IN ITS FIRST 150 YEARS

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> "The universal flux and flow of the world is seen also in our little college."
>
> (*Dalhousie Gazette* 1913:2)

The Nova Scotian Institute of Science's [hereafter NSIS] sesquicentenary in 2012 offers an opportune moment in the Institute's lengthy history to celebrate an impressive cumulative record of achievement over time. In so doing, we can assess the NSIS's place in the same "universal flux and flow of the world" that buffeted its partner institution, Dalhousie University, in a rapidly changing historical context. From its inception, the NSIS mandated annual assessments by its presidents, who have traditionally taken more detailed stock of its state of affairs at 25-year intervals (Piers 1915; Piers 1936; Fergusson 1964). To mark its 75th anniversary in 1937, NSIS members even contemplated commissioning a history for publication in a scholarly journal; the Council, however, tabled the suggestion in favour of a public event that would make a bigger splash (NSIS Council Minutes 1936: 26 October; NSIS 1936a).

In addition to the manuscript Minutes of NSIS meetings housed in the Nova Scotia Archives, the Institute's remarkable unbroken series of published *Proceedings and Transactions*[1] sheds valuable light on the ways in which discussion translated into action. This substantial cumulative historical record also reveals longterm challenges faced by an ambitious institution dedicated to "the promotion of science" – a mission that began as a measure of Nova Scotia's material and cultural progress in the modern world, changing its meaning over time in ways that repeatedly challenged the Institute's understanding of its place in that world.

[1] Less unbroken, however, are the NSIS membership records, reported only sporadically at best and often including names with unpaid dues. Membership numbers have, thankfully, been included once again, this time in NSIS Treasurers' annual reports, since 2004.

Recent scholarship has, in addition, deepened our understanding of time and place in the history of science and its institutions. On the temporal front, the historian John V. Pickstone identifies three predominant *Ways of Knowing* (2001) that have characterized the practices of science, technology, and medicine as they too changed over time. What Pickstone calls Natural Historical, Analytical, and Experimentalist Ways of Knowing each displaced – but emphatically did not replace – the others in a particular historical sequence. Before Pickstone, the early NSIS seemed to exemplify a natural history society; after Pickstone, we understand it more clearly as a creature of the 19th-century Age of Analysis, intended to promote the production of a specific range of scientific knowledge by analytical means, and to communicate the results in analytical forms. In a telling signal on this point, repeated NSIS efforts to organize the four annual field excursions required in its by-laws never attracted the following that natural history societies elsewhere were able to rally, and were soon discontinued (Gossip 1878:229; Ritchie 1926a:xxix; Fergusson 1962:233).

On the spatial front, the historical geographer David N. Livingstone's *Putting Science in Its Place* (2003) distinguishes three geographical dimensions in the production of scientific knowledge:the Sites (including field, museum, and laboratory) and Regions from which such knowledge emerges; and the patterns of Circulation that explain how (and in what forms) such knowledge travels from one place (and context) to another. Livingstone's spatial approach encourages historians of the NSIS to move beyond classic assumptions of a one-way diffusion of scientific knowledge and practice from imperial centres to colonial peripheries – or, for that matter, from Halifax to its provincial hinterland (Basalla 1963; Corfield 2003:90-92). Metropolitan approaches overlook Halifax's role as more complex than a mere harbour for British exploratory expeditions to replenish their supplies en route to somewhere else, on the one hand; they also overemphasize its role as the urban arbiter of Nova Scotian science, on the other hand.

When Britain's HMS *Challenger* docked at Halifax[2] in May 1873 during its pioneering scientific investigation of the oceans in various latitudes (Mills 1975; Mills 1989), one of its leading scientists, the Scottish marine zoologist Sir Charles Wyville Thomson (1830-82)

[2] So did its scientific predecessors HMSS *Porcupine* and *Lightning* (Honeyman 1874; Bailey 1972).

disembarked to visit with two Scottish colleagues, the botanist George Lawson (1827-95), who happened to be away, and the geologist David Honeyman (1817-89). Both were senior NSIS members, with Honeyman also founding curator of the NSIS's institutional offspring, the Nova Scotia Provincial Museum [now the Nova Scotia Museum of Natural History], established in 1868. These professional connections opened the *Challenger* to hundreds of interested Haligonians for an unforgettable guided tour – not only of the state-of-the-art "apparata" used to dredge new natural wonders from the ocean floor, but also of the scientists' ship-board working quarters. Before departing, the *Challenger* scientists enjoyed a field excursion with Honeyman guiding them to photograph local glacial striations at Point Pleasant (Fig 1), and accepting in return some coveted specimens recently raised from their deep-sea habitats (Honeyman 1873).

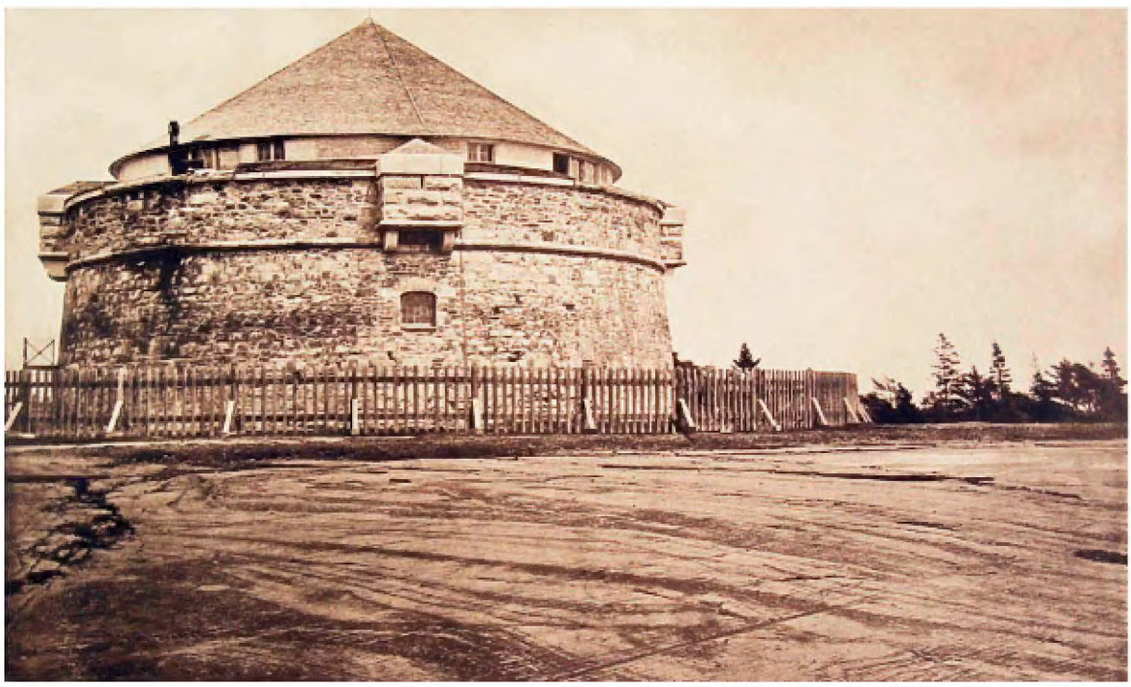

Fig 1 **"Rock with Glacial Markings, Halifax, Nova Scotia" (Source: C. Wyville Thomson and John Murray, Report of the Scientific Results of the Voyage of H.M.S. Challenger During the Years 1873-76, Vol. 1, Photographic Plate I (London: Eyre and Spottiswoode, 1885) 158, accessed 14 January 2014 http://www.19thcenturyscience.org/HMSC/HMSC-Reports/1885-Narrative/Plates.html).**

Pickstone's and Livingstone's insights alert historians to the significance of such transfers of knowledge between the NSIS, its wider Atlantic world, and indigenous and local informants (Jones 1867; Ambrose 1867); of the NSIS's purposeful inclusion of Prince Edward Island, Newfoundland, Labrador, and Bermuda in its purview (Hill 1867:4); and of the historical experiences – including a shift in

emphasis from the field to the laboratory – that compelled the NSIS time and again to reconsider its relationship to the place from which it took its name. Indeed, the history of its first fifty years reveals themes that would exalt – and challenges that would haunt – the NSIS for the fifty years that followed, with a return to more familiar ground thereafter.

SETTING SAIL

Established in 1749 as a crucial node of in an expanding British Empire, Halifax grew into a busy crossroads where an amalgam of cultures, among them strong Scottish influences, embraced science increasingly as indispensable to modern life. Yet early attempts, in the mode of the British amateur naturalist tradition, to organize formally those who shared a passion to observe, collect, describe, and classify the floral, faunal, and mineral denizens of Nova Scotia's remarkable landscape enjoyed little success before other important developments came into play. The 1860s were not an age for founding natural history societies, but rather for what Pickstone differentiates as Analytical work that built on, rationalized, and extended natural history's descriptive inquiries to support industrial development's voracious appetite for natural resources in a rapidly changing world.

During the uncertain decades after the end of the Napoleonic Wars in 1815, frustrations over Nova Scotia's economic future only intensified when the colony's most prominent scientist, (Sir) JW Dawson (1820-99), whose classic study of *Acadian Geology* made his name internationally in 1855, left that same year to become principal of McGill College, Montreal. While the end of the (British) General Mining Association's thirty-year monopoly over mineral rights in Nova Scotia in 1857 at last opened the colony's wealth of mineral resources to the possibility of a thorough scientific appraisal, American mining companies were eager to move in before that goal could be accomplished. Even when "gold fever" (Poole 1906:xx) gripped the colony during the 1860s, the Nova Scotia government resisted calls to appoint a geological survey on the model of Sir William Logan's Geological Survey of Canada, established twenty years earlier to locate, assess, and map whatever mineral deposits promised the United Province of Canada (now Ontario and Quebec) industrial wealth on the scale enjoyed by Great Britain and the United States (Nuftel 2003; Zeller 2009).

A. Foundations

The success of Nova Scotia's prize-winning mineralogical display at the Great London Exhibition in 1862 galvanized David Honeyman and a handful of fellow exhibition organizers later that year to convene the Nova Scotian Institute of Natural Science, a successor to the Halifax Mechanics' Institute (1831-62), the Halifax Literary and Scientific Society (1839-46) and the Nova Scotia Literary and Scientific Society (1859-62) (Piers 1915; Fergusson 1962). The reorganization of Dalhousie College in 1863 offered no hope of immediate reinforcement for the fledgling society, as dire financial difficulties precluded all scientific possibilities at the college for the time being – except for a much-needed NSIS meeting room and the arrival (as Professor of Chemistry and Mineralogy) of the botanist George Lawson, a refugee from an even more deeply troubled Queen's College, Kingston (Waite 1994, Chapter 5; Zeller 2003).

In favouring Ways of Knowing well beyond those practised in natural history, the NSIS saw continuing interest in observing, describing, and classifying nature open out to Analytical searches for units in nature as components of larger systems. While Natural Historical Ways of Knowing had recorded the process of *encountering* nature until about 1815, Analytical Ways of Knowing thereafter sought to impose order, to *subdue* nature (Wynn 2007), dissecting it to reveal its parts. The aim, in Pickstone's terms, was to "rationalize production," not only through mechanization but also by reconceptualizing even living organisms as components of processes that could be broken down, standardized, and, ultimately, commodified (Pickstone 2001: Chapters 2-3). For the fledgling NSIS, it was not simply a matter of engaging geology, mineralogy, and chemistry to harvest the colony's known mineral wealth more efficiently, but of promoting all branches of science that could help to rationalize fishing, farming, hunting, manufacturing, and other professional and commercial pursuits, with an eye to rendering every livelihood – and every worker – more productive (Dewar 1865; Reid 1876).

The early life of the NSIS drew Analytical inspiration from the "Prince of Modern Science," the recently "lamented" Prussian scientific traveller Alexander von Humboldt (1769-1859) whose widely admired works culminated in his multi-volume *Cosmos* (1845-62), an attempt at nothing less than a *Physical Description of the Universe* by investigating nature's underlying interconnectedness. The "distinguished modern," as Thomas Knight reminded the Institute in 1869, "was

the first who employed such wonderful powers of generalization in comprehending the vastness and oneness of nature" (Knight 1870:98). Humboldt lent these interconnections effective visual expression in the Analytical maps, isolines, tables, graphs, and charts that populated not only the *Atlas* that accompanied *Cosmos*, but also the pages of the *NSIS Proceedings and Transactions* with increasing sophistication over the years. Scientific knowledge accrued, in the Humboldtian view, through the cooperation of widely dispersed participants using standardized instruments in synchronized observations. In return, it promised the greatest possible accuracy in the search for patterns in nature that would ultimately reveal natural laws. Humboldt's world-wide networks of scientific communication and exchange constituted a feat of incredible proportions long before the internet enabled later generations to take WorldWide Webs of knowledge for granted. His Analytical leadership inspired British military officers and even fur traders to contribute to the growth of scientific knowledge from the far corners of the natural and physical world to which they travelled (Zeller 2012). In his inaugural presidential address, Nova Scotia's Provincial Secretary, PC Hill, reminded the NSIS of its important vantage point in this regard: "Nothing is more characteristic of the science of the present day," he pointed out, "than the value attached to facts verified and ascertained *in situ*" (Hill 1867:2).

From the outset, as a result, the NSIS determined to publish regular transactions not only for the regional value of its findings, which won government funding amid perennial hopes of undiscovered gold deposits – fortified by new geological theories for locating them (Gilpin 1878:387; Stafford 1989:19). The *Proceedings and Transactions* were, furthermore, intended to produce scientific knowledge that thus became "the property of the whole world" (Hill 1867:2), where the relevance of revolutionary new theories regarding the origin and distribution of species and the wonderfully transformative powers of energy science engaged early NSIS members in regular discussions (NSIS Council Minutes 1864: 7 November and 5 December; Belt 1867; Fraser 1868; Ross, 1874; Dewar 1879). Soon NSIS officers were proudly reporting its *Proceedings and Transactions* "in great demand" as far as Europe and even Australia (Mellish 1878:105; Gossip 1878:227).

The sweet smell of success in attracting public support inflated NSIS members' dreams: of an Academy or Hall of Science with the means to encourage further scientific investigation (Reid 1872a; Gossip 1884); of a provincial aquarium for the study of marine zoology

(Reid 1872a; Reid 1876:132-33, 135); of a provincial science library (Gossip 1878:228); of microscopes and other scientific instruments that could be lent out to NSIS members (Gossip 1879:105); and of a school of practical science to match recent achievements on this front in Toronto and Montreal (Zeller 2000). While announcements of a new Halifax Technological Institute, presided over by George Lawson and staffed by NSIS and Dalhousie College colleagues on a voluntary basis, attracted students eager for vocational training during the academic years 1878-80, high hopes for the necessary public funding – and even for a building – to keep it going were just as quickly dashed at every government level (Gilpin 1878:379; NSIS 1879).

The still-born Halifax Technological Institute exposed structural fault-lines that challenged the NSIS more generally throughout its history. First and foremost, geography conspired with 19th-century modes of travel to make it impossible (and later impractical) for even the most ardent supporters in the Nova Scotian countryside to attend meetings in Halifax on a regular basis (NSIS 1879). Some members also felt constrained by the NSIS's original vision: the Edinburgh-trained physician Dr. AP Reid (1836-1919) had urged the Nova Scotian Institute of Natural Science as early as 1872 to embrace the interest in modern physical science and technology already reflected throughout its *Proceedings and Transactions* (Reid 1872b). Despite resistance from George Lawson and others, Reid successfully moved a resolution in 1874 to divide the NSIS into three sections (Natural History, Ethnology, and Technology), a decision that altered little in the Institute's unified operations[3] (Reid 1874). A changing context, however, soon recast these discussions of the NSIS's structure, aim, and purpose.

B. Research Ideal

In 1882 the newly established Royal Society of Canada [hereafter RSC] introduced a powerful external force field that polarized the Institute. With an exclusive membership in two elite scientific (and two literary) academies (Levere 1998; Berger 1996), the RSC threatened to fracture the scholarly energies – if not the scholarly loyalties – of NSIS members who found themselves so anointed. Moreover, an RSC invitation to institutional membership, with expectations of

[3] These groups met occasionally outside of the formal framework of regular NSIS meetings; the index to the subsequent volume of the Proceedings and Transactions (Volume 3) – and only that one – was subdivided in a similar (but not identical) way.

a commitment to elect representatives and send reports to its annual meetings, sparked concerns for the NSIS's future independence.[4]

Of the six NSIS members who were named RSC charter fellows, five had longstanding NSIS ties.[5] The sixth, the dynamic James Gordon MacGregor (1852-1913), had joined in 1877. A prize-winning Dalhousie graduate (BA 1871; MA 1874), MacGregor had proceeded overseas on a Gilchrist Scholarship, first to the University of Edinburgh, where he spent invaluable time in the laboratory of the renowned physicist Peter Guthrie Tait[6] (1831-1901); and then to the University of Leipzig, where he cemented a lifelong research interest in thermal and electrical chemistry in the laboratory of the physical chemist Gustav Wiedemann (1826-99). MacGregor then completed a DSc at the University of London in 1876. Stints as a sessional lecturer in physics at Dalhousie (1876-77) – strongly supported by the NSIS (Gossip 1876) – and then as physical science master at Clifton College, Bristol (1877-79) came to a merciful end when the unprecedented endowment that saved Dalhousie from financial collapse (and the death of its physics professor, JJ MacKenzie) in 1879 afforded MacGregor's appointment to the inaugural George Munro Chair of Physics (Waite 2003; NSIS 1919b:lxxxvi; Knott 1913:323).

In keeping with his specialization in the cutting-edge field of thermodynamics, MacGregor showed himself a force of nature who reconfigured the NSIS in his own image of Analytical science as the path to progress in the modern world. In so doing, he exposed the RSC's divisive impact through an open challenge to Dr. John Somers (?-1898), the NSIS president, whose (unpublished) annual address in 1882 criticized the RSC's letter of invitation for unduly patronizing the NSIS. In a blatant rebuke of Somers, MacGregor, seconded by George Lawson, steered a discussion to welcome the RSC's invitation and to elect a delegate to its inaugural meeting in Ottawa (NSIS Council Minutes 1883:2, 8, and 31 January).[7]

[4] The NSIS was not alone in these concerns (Lawson 1889: 1-3; Grant 1892:xxxi).

[5] They were Edwin Gilpin (1850-1907), JB Gilpin (1810-92), David Honeyman, JM Jones (1822-88), and George Lawson.

[6] Tait was one of the North British researchers who, led by William Thomson (later Lord Kelvin) (1824-1907) was revolutionizing classical physics through the powerful new science of heat as a form of energy, thermodynamics, with brilliant applications of mathematical analysis to improve the efficiency of steam-based machinery (Smith 1999).

[7] MacGregor then turned his critical eye toward RSC procedures at its Halifax meeting in 1897 (MacGregor: personalia (1913):28).

Nor did the election of William Gossip (1809-89), a Halifax publisher, NSIS Council member, and founding editor of its *Proceedings and Transactions*, bridge the fundamental gap between NSIS specialists and generalists. Gossip arrived at the RSC meeting to confess that he had prepared no report on NSIS activities, submitting instead a personal commentary on the RSC's responsibilities towards its affiliated societies; it was all MacGregor could do to dissuade him from reading the statement into the RSC Minutes.[8] Gossip reported back to the NSIS in descriptive detail the impressions of a neophyte railway traveller, Ottawa tourist, and conference participant who harboured serious misgivings about the RSC's organizational structure, especially with its membership "numbers so unwisely limited" (Gossip 1884; Gossip 1885). While MacGregor conceded that the RSC was indeed siphoning off the *NSIS Proceedings and Transactions*' best papers, he held out hope that "before very long, the establishment of the Royal Society may result in a stimulus which will produce so much energetic work, that the Transactions of both the central and the local Societies may be large as to number and valuable as to contents" (MacGregor 1886b:x). Before very long, however, the NSIS found itself permitting papers presented at its meetings to be published in its *Proceedings and Transactions* even when they were also committed elsewhere (NSIS Council Minutes 1895:31 December ; MacGregor 1898:xxvi).

MacGregor described this change in NSIS policy as "a great relief" (MacGregor 1898:xxvi), since both he and Lawson thrived in their more expansive scholarly environment. Lawson, in particular, had made clear that he had hesitated to publish in the *Proceedings and Transactions* while the NSIS "made little effort to distribute its publications among scientific societies" (Hall 1896). Having imbibed the German research ideal, which advocated scientific research "for its own sake," independent of metaphysical or religious concerns[9] (McKillop 1982:79-80; McKillop 1994:Chapter 7), MacGregor set about modernizing the NSIS – and with it Nova Scotian science

[8] The RSC *Proceedings* listed Gossip's submission among those that "gave to the meeting encouraging oral statements of the work that was being done" (RSC 1883:xlv).

[9] As one memorialist later explained, MacGregor's "personal philosophy took shape in the time of the great [John] Tyndall [materialist] and [Thomas] Huxley [agnostic] wars with accepted beliefs" (MacGregor: personalia 1913:28). George Lawson, with a DPhil and laboratory experience from the University of Giessen, shared the German research ideal; as RSC vice president in 1887, he repeated the mantra that "Science is best pursued for its own sake" (Lawson 1888:xxiv).

education – to promote "knowledge-making" accordingly (MacGregor 1899). In 1884, after initiating a worldwide RSC survey of scientific institutions' means of funding research, he revised the NSIS by-laws to specify as the Institute's single object "the promotion of scientific research," which he deemed, in characteristic Analytical style, "essential to the promotion of our industrial development" (RSC 1883:xv; MacGregor 1886a; NSIS Minutes 1884:24 October; NSIS 1885:1; cf. NSIS 1863:1; MacGregor 1890b:328).

MacGregor's election to the NSIS presidency in 1888 followed the Institute's first 25-year mark with still more far-reaching changes. In an unprecedented flurry of NSIS activity, he introduced an integrated plan to strengthen the Institute and, along with it, science education across the province (MacGregor 1899). The linchpin was to be the Provincial Museum, with the NSIS driving the Museum's development as the repository for a new provincial science library, a showcase for the province's natural resources, and the locus for a range of new science educational opportunities, both specialized and popular. Recalling the trials of the nascent Halifax Technical Institute – to which he had been deeply committed as a leading protagonist – MacGregor revived his mission to interest Nova Scotians in science, both "pure and applied" (MacGregor 1890b; NSIS 1919b:lxxxviii).

In 1890 MacGregor accordingly rebranded the NSIS to acknowledge certain realities. "The scope of [its] exertions," he explained, had "got beyond the range of the departments of science indicated by its name." More pointedly, "the old name" created impressions of "a society of naturalists," thereby "repress[ing] the interest which [those] engaged in other departments of work might have taken in it." As such, it "hamper[ed] ... our endeavour to secure by exchange the publications of other societies ... devoted to departments not usually included under the term Natural Sciences." MacGregor accordingly urged the NSIS formally "to extend its field to all departments of science, pure and applied, encourage research in all such departments and build up, by exchange, a library for the use of those engaged in them." A special meeting in March marked the end of an era in NSIS history by amending its name (choosing "Nova Scotian Institute of Science" over "Nova Scotian Scientific Institute") and securing the organization's incorporation later that same year. Eyewitness recollections long afterwards denied the unanimity so starkly recorded

in the NSIS Minutes,[10] instead citing "considerable opposition" that persisted for decades and included "one of the most learned biologists of the United States"[11] (NSIS Minutes 24 March 1890; Fergusson 1962:236; Piers 1915:lxxi-lxxiii; Ritchie 1926:xxxi).

MacGregor hoped, above all, to breathe new life into the Institute's memberships and exchanges. In charts and graphs[12] that again reflected his Analytical approach, he assessed the NSIS's historical record of achievement (MacGregor 1890a:185-186) along three axes that comprised its mandate: not just "investigating" and "providing the means of investigating," but also, he explained, "stimulating the love of investigation" – the last having grown more difficult as even the comprehension, let alone the practice, of science required increasingly specialized training (MacGregor 1890a:189). Embarking on a tireless science awareness campaign throughout the province, MacGregor targetted school teachers and their students as potential NSIS members, urging NSIS colleagues similarly to extend invitations to friends and acquaintances. In a related move, as editor of the *Proceedings and Transactions* (1890-1901), he raised the journal's print run to an unprecedented 1000 copies, adding 300 international exchanges during the first year alone, with a "phenomenal" upward trajectory that garnered government funds to ease the burden of mailing, binding, cataloguing, storing, and insuring the rapidly growing core of what became the new Provincial Science Library in 1890 (Fig 2) (NSIS Council Minutes 1890s, *passim*; MacGregor 1892ab; Ritchie 1926a:xxix). A concomitant rise in NSIS memberships (Fig 3) reflected growth especially in the Associate and Corresponding member categories (figs. 4 and 5).

In 1891 the indefatiguable MacGregor completed three eventful years as NSIS president, regretting his failure to secure a building for the Provincial Museum, a goal that would have to wait another ten years before it saw the light of day (MacGregor 1892b:xxxiv).

[10] Harry Piers's later claim that John Somers led a group of older opponents to the name change fits with Somers's refusal as a physician, even during the mid-1890s, to accept scientific research that supported the germ theory of disease. The literature also hints at another longterm rivalry, between Edinburgh- and Aberdeen-based traditions in scientific training (Lawson 1896:vi-vii; Howell 2003).

[11] This was likely the New Brunswick-born W.F. Ganong (1864-1941), Professor of Botany at Smith College, who joined the NSIS as a Corresponding Member in 1890 (Bean 1942:289-90); that same year, Ganong co-authored a paper with Harry Piers, whose recollection is cited above on this point.

[12] The NSIS archives have, unfortunately, no copies.

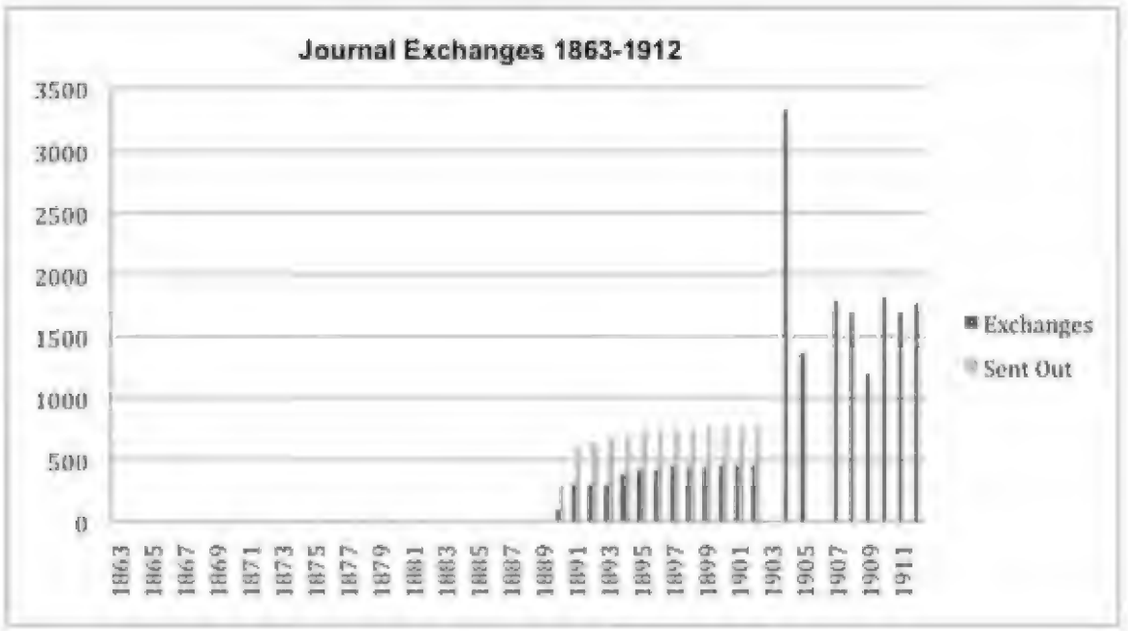

Fig 2 **NSIS Journal Exchanges, 1863-1912.**

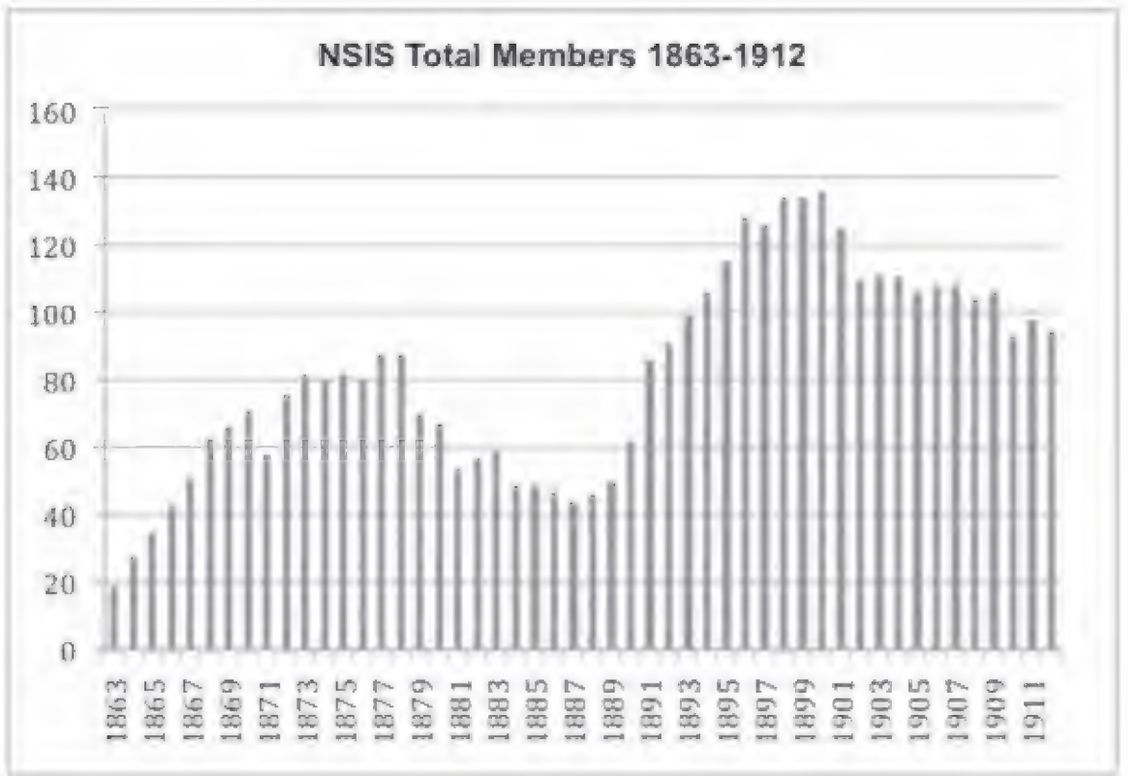

Fig 3 **NSIS Total Members, 1863-1912.**

Soon thereafter, however (and twelve years after his initial efforts), he welcomed Dalhousie College's new Faculty of Pure and Applied Science as its founding Dean. MacGregor's successor as NSIS president, the civil engineer Martin Murphy (1832-1926), expressed appreciation that "at no time in its past history was our Institute of Science more assiduously cultivated than during the term of office of

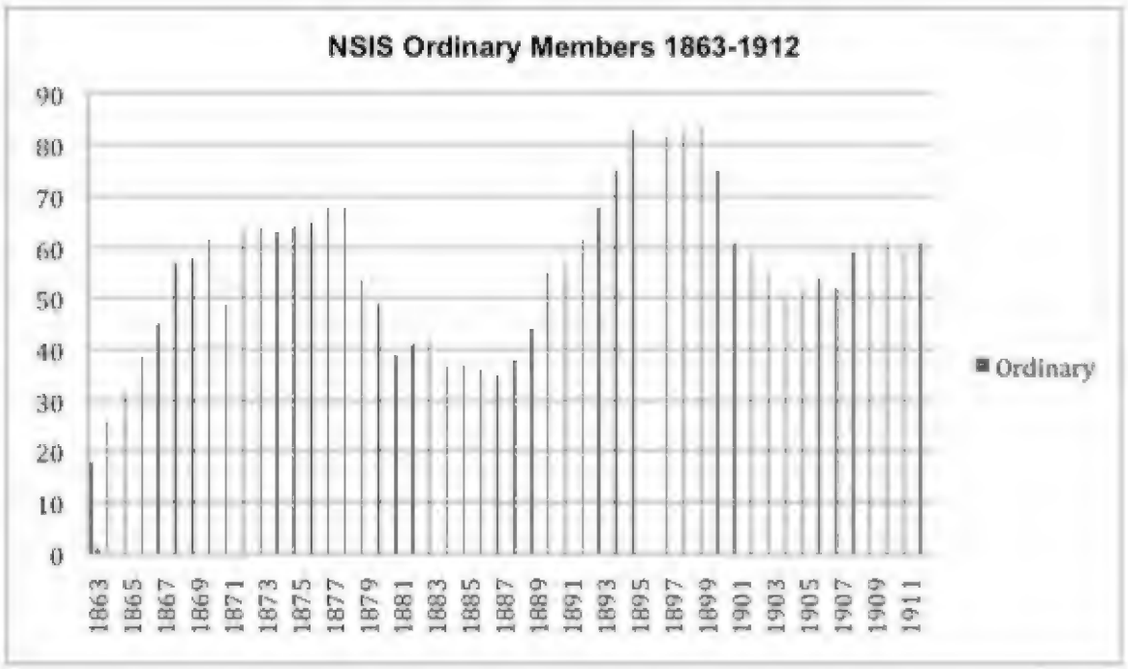

Fig 4 **NSIS Ordinary Members, 1863-1912.**

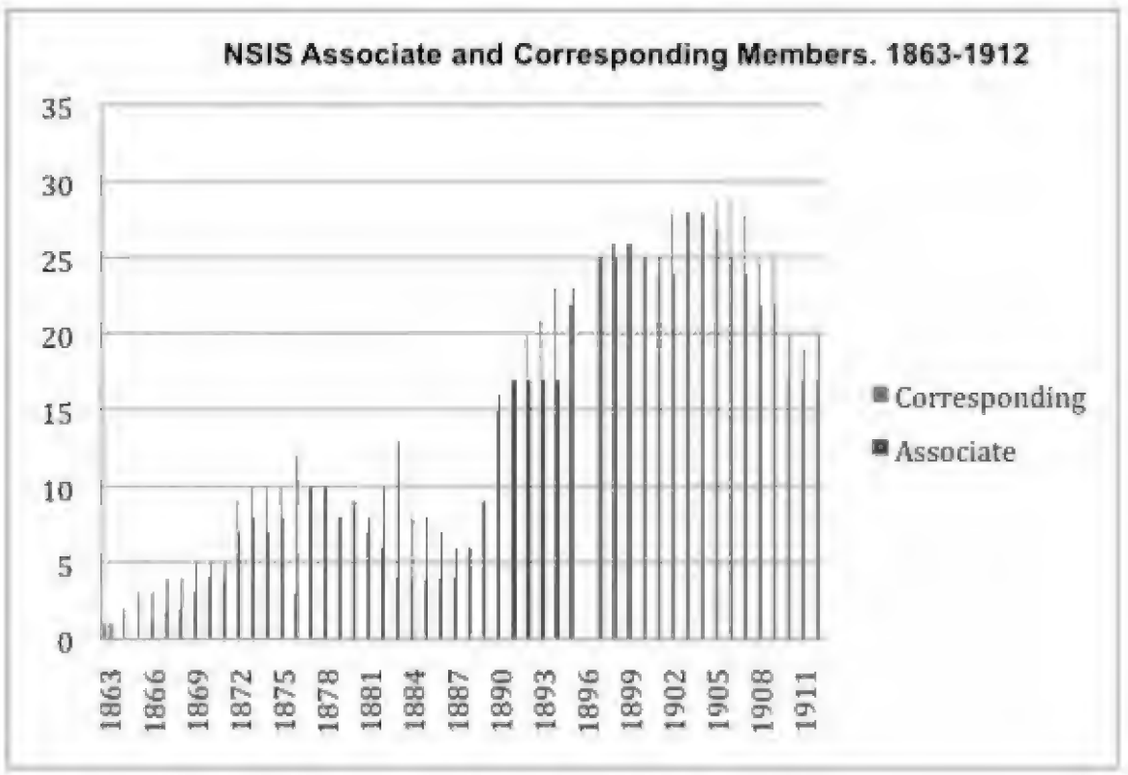

Fig 5 **NSIS Associate and Corresponding Members, 1863-1912.**

the late President; nor does his zeal end here: he is ever active for the promotion of its interests" (Murphy 1893:xlviii). George Lawson expressed similar presidential admiration in 1894: thanks to MacGregor, he acknowledged, "there is now no country under the sun whose scientific societies (where such exist) do not have our Transactions on their library shelves as exchanges for their own" (Lawson 1896:x).

More than forty years later, MacGregor's name still evoked fond memories as *the* outstanding "young, auburn-haired, keen-eyed, vivacious and quick-witted" NSIS president[13] (Piers 1936:200).

C. Humboldtian Project

MacGregor's sharp analytical instincts and organizational abilities also embraced a strong conviction of the timeliness of "collective scientific work," once inspired directly by the Humboldtian ideal and now epitomized by the (also Humboldt-inspired) British Association for the Advancement of Science [hereafter BAAS] (BAAS 1885; MacLeod 1981). He joined the BAAS for its Montreal meeting in 1884, when NSIS members also hosted local excursions for overseas delegates who travelled through Halifax (Honeyman 1885). Of particular interest at that meeting was a joint BAAS-RSC resolution (framed by a BAAS committee that included MacGregor) to lobby the federal government for systematic tidal and current observations in Canadian waters[14] (BAAS 1885:lxxiii; Lawson 1889:3). As the NSIS delegate to the RSC meeting the following year, MacGregor proposed an RSC committee to design a centralized programme of "simultaneous observations over the whole country" of various periodic natural phenomena, including bird migrations (MacGregor 1886b). As NSIS president in 1888, he reiterated his call for an RSC-administered programme of "collective investigation," citing a list of relevant subjects for which the NSIS could, in turn, serve as a regional coordinator.[15] The timing seemed especially appropriate in light of MacGregor's overall plan to recruit observers by cultivating the interest and cooperation of science teachers throughout the province (MacGregor 1890a:189-190). When the RSC finally appointed a committee for this purpose in 1890 (MacGregor 1890b:iv; RSC 1891:xliv, xlvi; RSC 1892:lxiv), other favourable factors were also falling into place.

In 1891, George Lawson organized a Botanical Club of Canada under RSC auspices, with representation to be drawn from affiliated societies across the country. As its founding president, Lawson

[13] The NSIS received a portrait of MacGregor in 1918 (NSIS 1919b).

[14] MacGregor also served on the RSC committee that reported some success in lobbying the federal government for this purpose in 1890; in that capacity he distributed printed circulars to maritime shipowners to invite their observations of tides and ocean currents (RSC 1891:viii-ix; Johnson 1891).

[15] These included "the flowering of plants, the migration of birds, the movements of fish, the first appearance of insects," along with meteorological, geomagnetic, and tidal phenomena.

envisioned the new society as the central clearing-house for a national "army of explorers" to collect seasonal floral data (Lawson 1892:20; RSC 1892:lxiv). As a botanist, he saw more clearly than MacGregor did, that new anatomical and physiological approaches at the cutting edge of the study of plants were critically diminishing the numbers of field workers emerging from universities. Like MacGregor, Lawson saw a potential solution in the growing numbers of science educators who could – along with their students – be recruited to form, in Lawson' charming phrase, a dedicated "band of gleaners" (Lawson 1892:19-20).

While Lawson and MacGregor lent their broader scientific vision to this Humboldtian project, it was the Botanical Club's first secretary, the Nova Scotia-born Alexander Howard MacKay (1848-1929), whose Herculean efforts lent it longevity with increasing analytical sophistication. MacKay had attended Pictou Academy and trained as a teacher before graduating with a BA in mathematics and physics (Dalhousie University, 1873) and a BSc in biology (University of Halifax, 1880). He joined the NSIS in 1885 while principal of Pictou Academy, where he renewed the science programme and established a provincial Summer School for Science to upgrade teachers in Nova Scotian schools. Elected an RSC member in 1888 as a field researcher of Nova Scotia's flora and fauna, MacKay moved to direct the Halifax Academy in 1889 before becoming Nova Scotia's Superintendent of Education in 1891. By introducing nature study into the schools as research experience for young students (Guildford 2003), MacKay was ideally positioned to carry out the phenological programme framed by MacGregor and Lawson.

The *NSIS Proceedings and Transactions* had regularly published separate Nova Scotian meteorological tables and floral and faunal lists. What distinguished the phenological programme undertaken by the Botanical Club of Canada was its interest in coordinating and correlating on a provincial, regional, and even national scale observations of meteorological and other physical phenomena, along with seasonal signals in the natural world, including first sightings of migrating birds and leafing and flowering plants. MacKay began in 1892 with a handful of observers across Nova Scotia and a single analytical innovation, listing days of the year by their ordinal values from 1 to 365 (Fig 6) (RSC 1891:xliv; MacKay 1893). A year later he added stations in New Brunswick, and began averaging dates by their ordinal values to calculate annual "normals" of the various phenomena

NATURAL HISTORY OBSERVATIONS, NOVA SCOTIA, 1892. FIRST APPEARANCES DATED BY THE DAY OF YEAR.

Plants.	Yarmouth.	Mahone Bay, Lunenburg Co.	Windsor, Hants Co.	Several Stations, Kings Co.	Springhill, Cum. Co.	Amherst, Cum. Co.	Average of Dates at Nova Scotian Stations.	Average Date—Day of Month.
Alder, (pollen)	....	97	97	....	113	....	102	12 April.
Aspen, (")	....	....	....	121	143	128	131	11 May.
" (leaf)	....	152	147	152	....	....	150	30 May.
Red Maple, (flower)	....	118	121	110, 121	141	130	121	3 May.
Dog-tooth Violet, (flower)	....	....	....	....	135	....	135	15 May.
Mayflower, (")	86	....	90	91, 97, 110	105	....	98	8 April.
Dandelion, (")	103	125	128	124, 130, 135	135	131	126	6 May.
Strawberry, (")	113	127	135	129	134	130	129	9 May.
" (fruit)	....	201	203	201	....	....	202	22 June.
Cherry, Cultivated, (flower)	....	153	144	139, 142	....	156	146	26 May.
" " (fruit)	....	203	....	....	....	....	203	23 June.
Wild Red Cherry, (flower)	....	150	147	....	152	....	150	30 May.
Indian Pear, (")	....	....	144	....	140	146	145	25 May.
Apple, Cultivated, (flower)	126	152	151	146, 147	152	....	140	29 May.
Hawthorn, (")	....	....	....	160, 166	....	....	163	12 June.
Lilac, (")	....	163	150	140, 151, 158	....	165	154	3 June.
Wheat sown (spring)	....	....	....	121	119	....	120	30 April.
Birds.								
Song Sparrow	....	....	91	92, 105, 116	....	....	99	9 April.
Robin	....	104	91	88, 91, 92, 110	....	....	98	8 April.
Snow Bird	....	....	....	90	....	....	90	31 Mar.
Spotted Sand Piper	....	....	136	120, 121, 130	....	....	126	6 May.
White Bellied Swallow	....	....	114	117, 119, 105, 133	....	....	106	16 April.
Kingfisher	....	....	130	130, 135, 138, 140	....	....	128	8 May.
Humming Bird	....	....	....	139, 147, 149, 151	148	....	143	23 May.
Night Hawk	....	....	150	149, 147, 152, 154	155	....	150	30 May.
Wild Goose, (first)	....	....	54	....	....	....	54	23 Feb.
" (last)	....	....	90	....	....	....	90	31 Mar.
Frogs { Croaking and Piping.	....	....	{ 100 / 114	111	....	....	{ 105 / 114	{ 15 April / 24 April.

Fig 6 **Natural history observations, made at several stations in Nova Scotia during the year 1892 (MacKay (1893):379).**

under scrutiny (MacKay 1894). In 1894 he added a station in Winnipeg, and continued drawing "inductions" from the information that had begun to accumulate (Fig 7) (MacKay 1896a). In 1895 he added a Vancouver station, explaining that he had also inducted students to participate en route to and from Nova Scotian public schools, with teachers submitting tabulated results in 100 (and eventually 200) categories. MacKay reduced these tables to an overall analytical picture that, he believed, sharpened with every additional observer at every additional station (Fig 8) (MacKay 1896b).

MacKay recognized the composite image taking shape before him as an increasingly valuable climatic record with both historical and geographical dimensions. His calculated "normals" revealed patterns of continuity and change across time and space, demarcating ten "meteorological or biological regions" across Nova Scotia, where

TABLE A.—PHENOLOGICAL OBSERVATIONS FOR 1894 IN THE ATLANTIC PROVINCES AND WINNIPEG.

Giving the day of the year (by number) of the first appearances of each column of the table below. Last day of Jan., 31; Feb., 59; Mar., 90; April, 120; May, 151; June, 181; July, 212; Aug., 243; Sept., 273; Oct., 304; Nov., 334; Dec., 365.

Number.	Phenomena.	Yarmouth, N. S.	Shelburne, N. S.	Halifax, N. S.	Musquodoboit Harbor, N. S.	Berwick, N. S.	Wolfville, N. S.	Southern Nova Scotia.	Port Hawkesbury, N. S.	Antigonish, N. S.	Pictou, N. S.	Wallace, N. S.	Northern Nova Scotia.	Nova Scotia.	Charlottetown, P. E. Island.	Grand Harbor, Charlotte, N. B.	Richibucto, N. B.	Dalhousie, N. B.	New Brunswick.	Atlantic Provinces.	Winnipeg, Manitoba.
1	Alder. Shedding pollen	113	107	112	110	119	114		135	..	112	109	118.0	116.3	....	108	....	110	113.5	111.0	.....
2	Aspen "	....	120	....	....	123	121.5		130	..	110	..	123	121.2	....	118	....	122	120	121.1	121
3	" Leafing out	....	110	....	....	147	134.5		155	..	150	..	152.5	148	....	111	....	....	114	146.	134
4	Red Maple. Flowering	120	118	137	134	115	121	140	132	123	120	128.7	126.8	....	120	130	131	132	129.1	.....
5	Hepatica. "	....	....	....	....	128	122	....	....	127	..	127	124.5	....	....	....	....	....	....	124.5	.....
6	Adder's Tongue Lily. Flowering	....	....	....	....	138	135.5	....	....	120	..	120	122.2	....	....	....	....	133	133	132.6	.....
7	Mayflower. "	99	101	71	110	...	112	63.8	121	117	110	115	115.7	101.7	121	115	117	....	116	111.2	.....
8	Dandelion. "	112	121	137	137	132	130	128.6	138	127	131	137	133.3	130.9	....	....	....	133	133	131.9	110
9	Strawberry, (wild). "	111	124	139	138	120	133	128	140	130	128	137	135.2	131.0	144	131	135	132	132.6	130.1	114
10	" (cultivated). Ripe Fruit	150	...	167	....	162	160	161.0	180	..	..	171	178.5	170.	....	167	173	....	170	170.	163
11	Cherry, (cultivated). Flowering	....	....	....	....	140	140	140	150	..	153	140	152.6	146.8	....	....	153	157	155	150.0	.....
12	" " Ripe Fruit	....	....	....	....	196	....	190	213	..	..	..	213	204.5	....	....	....	200	200	200.7	.....
13	Wild Red Cherry. Flowering	142	121	155	153	132	145	141.0	....	151	..	151	152.5	147.	....	157	..	160	156.5	151.8	110
14	Indian Pear. "	138	131	142	140	...	139	140	153	152	151	..	152	146.	....	138	....	153	145.5	145.7	149
15	Ripe Fruit	....	....	....	....	....	....	....	223	..	..	..	223	223.	....	....	....	....	....	223.	.....
16	Apple, (cultivated). Flower	111	....	....	162	133	140	140.5	165	152	152	150	154.7	152.1	....	161	155	....	158	155.	.....
17	Oaks. Flowering	175	....	....	....	152	137	141.3	....	....	....	..	....	161.3	....	....	....	....	....	161.3	141
18	Hawthorne. Flowering	168	156	170	170	150	150	153.0	..	....	....	157	157	160.3	....	....	160	....	160	161.0	141
19	Lilac. "	103	....	169	170	153	157	162.4	167	161	..	150	162.3	162.3	....	168	161	....	161.5	163.4	.....
20	Raspberry, (wild). Fruiting	....	....	211	....	196	200	203.5	213	..	..	..	213	208.2	....	200	....	202	201	208.1	.....
21	Wheat, (Spring). 1st sowing	....	....	....	....	....	....	....	....	..	..	..	....	....	....	....	....	132	132	132.	100, 131
22	" Harvesting	....	....	....	....	247	....	247	....	..	..	..	....	247.	....	....	....	250	250	243.5	247
23	Song Sparrow. 1st Appearance	....	....	99	....	98	70	80	101	..	97	..	71	70.	....	....	....	90	90	87.5	.....
24	American Robin. "	99	79	74	....	91	77	79.2	87	..	82	99	76.3	73.2	....	....	....	100	100	80.0	105, 112
25	Spotted Sandpiper. "	....	....	144	....	124	....	134	140	..	127	..	130.5	125.2	....	....	....	133	133	144.1	.....
26	Swallow. "	100	109	116	....	110	120	120	111	..	130	..	118	..	121	119.0	....	107	....	140	128	123.5	147
27	Kingfisher. "	....	118	133	....	112	....	....	123	..	159	..	115	..	130.5	128.7	....	....	....	....	....	128.7	.....
28	Hummingbird. "	137	....	....	....	130	137	130.0	150	..	..	140	140.5	143.0	....	....	....	157	157	150.	.....
29	Night Hawk "	....	....	144	....	140	....	....	142	..	163	..	175.0	158.8	....	132	....	....	132	155.1	145
30	Wild Ducks. First Birds	....	....	....	....	100	....	....	100	..	..	..	..	100.	....	....	....	....	....	100.	100
31	" First Flock	....	....	98	....	100	....	....	84	..	..	..	..	84.	....	....	....	....	....	84.	100
32	" Migrating South	....	....	....	....	238	....	....	278	269	..	..	..	263	....	320	....	....	320	293.2	.....
33	Wild Geese. First Birds	....	....	....	....	...	....	....	....	77	...	69	67	70.6	70.0	....	....	....	80	69	70.8	100
34	" First Flock	82	....	....	....	....	....	....	82	95	...	..	..	95	95.	....	....	....	98	98	96.5	102
35	" Migrating South	....	....	....	....	337	....	....	337	....	..	340	350	345	341.	....	....	....	....	....	341.	.....
36	Frogs' heard	99	100.	112	....	108	111	100.0	125	..	..	...	113	119	112.8	....	111	....	110	118.5	113.1	113

Fig 7 Phenological observations made at several stations in eastern Canada during the year 1894 (MacKay (1896a):60-61).

NOVA SCOTIAN PHENOCHRONS, 1902.

FLOWERING AND OTHER PHENOCHRONS FOR EACH REGION OF THE PROVINCE OF NOVA SCOTIA, COMPILED FROM 350 PUBLIC SCHOOL OBSERVATION SCHEDULES.

[The phenochrons for each region which are averages of many observations) have the fractions omitted.]

WHEN FIRST SEEN. — REGIONS. 1. Yarmouth and Digby.	2. Shelburne, Queens and Lunenburg.	3. Annapolis and Kings.	4. Hants and South Colchester.	5. Halifax and Guysboro.	6. South Cobequid Slope (S. Comb. and Col.)	7. North Comb., Col., Pictou and Antig.	8. Richmond and Cape Breton.	9. Bras d'Or Slope (Inv. and Victoria.)	10. Inverness Slope to Gulf.	Average for Province.	Number.	Day of the year corresponding to the last day of each month.		WHEN BECOMING COMMON — REGIONS. Average for Province.	1. Yarmouth and Digby.	2. Shelburne, Queens and Lunenburg.	3. Annapolis and Kings.	4. Hants and South Colchester.	5. Halifax and Guysboro.	6. South Cobequid Slope (S. Comb. and Col.)	7. North Comb., Col., Pictou and Antig.	8. Richmond and Cape Breton.	9. Bras d'Or Slope (Inv. and Victoria).	10. Inverness Slope to Gulf.
												Jan . 31	July. .. 212											
												Feb .. 20	Aug ..243											
												March ... 90	Sept 273											
												April.....120	Oct.. 304											
												May ... 151	Nov..... 334											
												June ... 181	Dec 365											
94	83	98	85	101	90	88	99	93	96	93.5	1	Alnus incana, Willd.		101 0	107	96	103	98	....	103	95	104	99	102
103	105	108	94	....	98	102	99	105	111	103.5	2	Populus tremuloides, Michx.		112 3	120	118	114	104	....	110	106	112	111	118
186	88	90	92	90	101	101	98	98	103	94.9	3	Epigæa repens, L.		107.4	103	101	103	105	107	110	109	108	112	113
113	117	115	117	121	118	120	125	121	124	119.1	4	Viola cucullata Gray		127.0	118	126	126	127	130	128	127	131	129	129
110	111	115	115	115	115	117	123	121	123	116.9	5	V. blanda, Willd		124.9	119	122	123	121	121	125	125	130	128	123
118	115	116	111	116	115	117	124	125	117	117.1	6	Acer rubrum, L.		123 6	125	122	121	119	124	124	121	129	128	123
130	127	130	132	125	127	....	....	....	146	131.6	7	Houstonia cærulea, L.		139.3	.	134	135	141	138	133	. .	....	....	151
120	125	114	110	. .	118	121	123	140	129	122.4	8	Equisetum arvense, L.		130 2	133	132	125	120	..	129	127	134	134	128
111	119	117	118	118	121	120	128	122	123	119.6	9	Taraxacum officinale, Weber. . .		129.0	121	127	127	127	133	131	129	133	129	131
127	152	135	128		126	121			126	130.8	10	Erythronium Americanum, Ker.		138 4	127	136	158	134		134	128	.	.	135
123	117	99	130							117.4	11	Hepatica triloba, Chaix		123.4	129	125	102	137	....	....	....	....	....	....
120	125	129	127	126	126	132	133	130	131	128 3	12	Coptis trifolia, Salisb		135.3	129	134	130	130	136	134	130	130	138	140
116	119	114	116	117	116	119	122	119	118	117.6	13	Fragaria Virginiana, Mill		129.2	123	129	126	127	132	129	130	129	140	129
*157	163	157	164	167	165	167	178	175	172	166 6	14	" (fruit ripe) .		178.1	174	176	173	177	179	171	180	186	184	182

*Last year the date here should have been 1st instead of "114" which was a clerical error.
†The "151" of last year should have been 158.

Fig 8 Phenological observations in Nova Scotia and Canada, 1902 (MacKay (1905b):148-149).

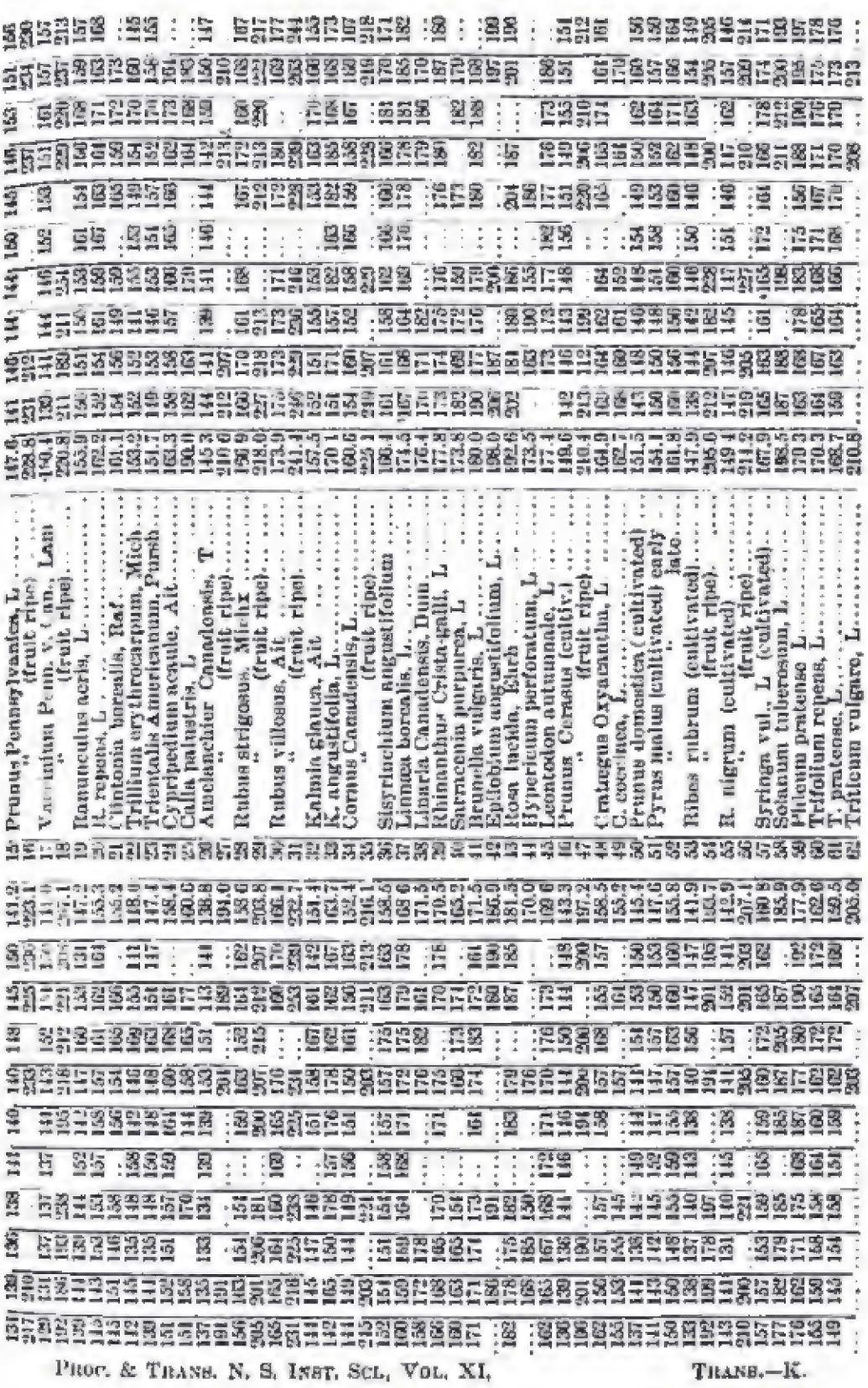

Fig 8 *(Cont.)* Phenological observations in Nova Scotia and Canada, 1902 (MacKay (1905b):148-149).

he had the greatest number of observations to work with. He called his calculated mean dates of seasonal occurrences "phenochrons," which he tabulated and then duly graphed and mapped in search of additional "inductions" (Fig 9) (MacKay 1897; Mackay 1899; MacKay 1905:145). By 1899 he was processing reports from 725 Nova Scotian school districts, along with thirteen stations across the rest of the country through the RSC's affiliated societies. Besides the mean values that MacKay calculated over several years, he ran his phenochrons through specific geographical regions as the data – now including seasonal animal sightings, storms, and agricultural activities (Fig 10) – accrued from year to year, and added earthquakes after one rocked the province in 1904. MacKay's project reached an interpretive peak in 1910[16] as he mapped the geographical patterns of seasonal changes across Nova Scotia, identifying "slopes" and "belts" that subdivided the province's climatic regions into zones (Fig 11). Despite declining numbers of student participants thereafter, the observations continued in Nova Scotian schools until he retired in 1924 (MacKay 1900; MacKay 1902a; MacKay 1905b).

MacKay housed both the voluminous tabulated submissions as well as his own meticulous compilations at the Provincial Museum. His pioneering analytical methods, derived from his training in physics, inspired similar projects in Britain, Germany, and Denmark (MacKay 1903:488). As "the world's largest database of its kind," the project earned renewed scientific recognition during the 1990s as "an important benchmark for assessing climate change" (Fenech 1999; Austen 2000; Guildford 2003; Fenech 2005; Zwarenstein 2010) and a revival by Nova Scotian students in the Thousand Eyes Project.[17]

D. Parting Ways

For all that MacKay's labour-intensive phenological programme continued well into the 1920s, it represented, in its close ties to place, the exception rather than the rule of science in its day. In 1902 he himself recognized a bitter irony in the fact that the NSIS's "audiences have been worldwide, but not local" (MacKay 1905a:v). Indeed, the research ideal reflected in MacGregor's influence upon the Institute had, by the 1890s, seen Analytical Ways of Knowing superseded by

[16] MacKay had by then taken on other heavy responsibilities: head of the new Department of Technical Education (1907); editor of the *NSIS Proceedings and Transactions* (1908); and NSIS Council member and president (Guildford 2003).

[17] http://suite101.com/a/thousand-eyes-project-a206984.

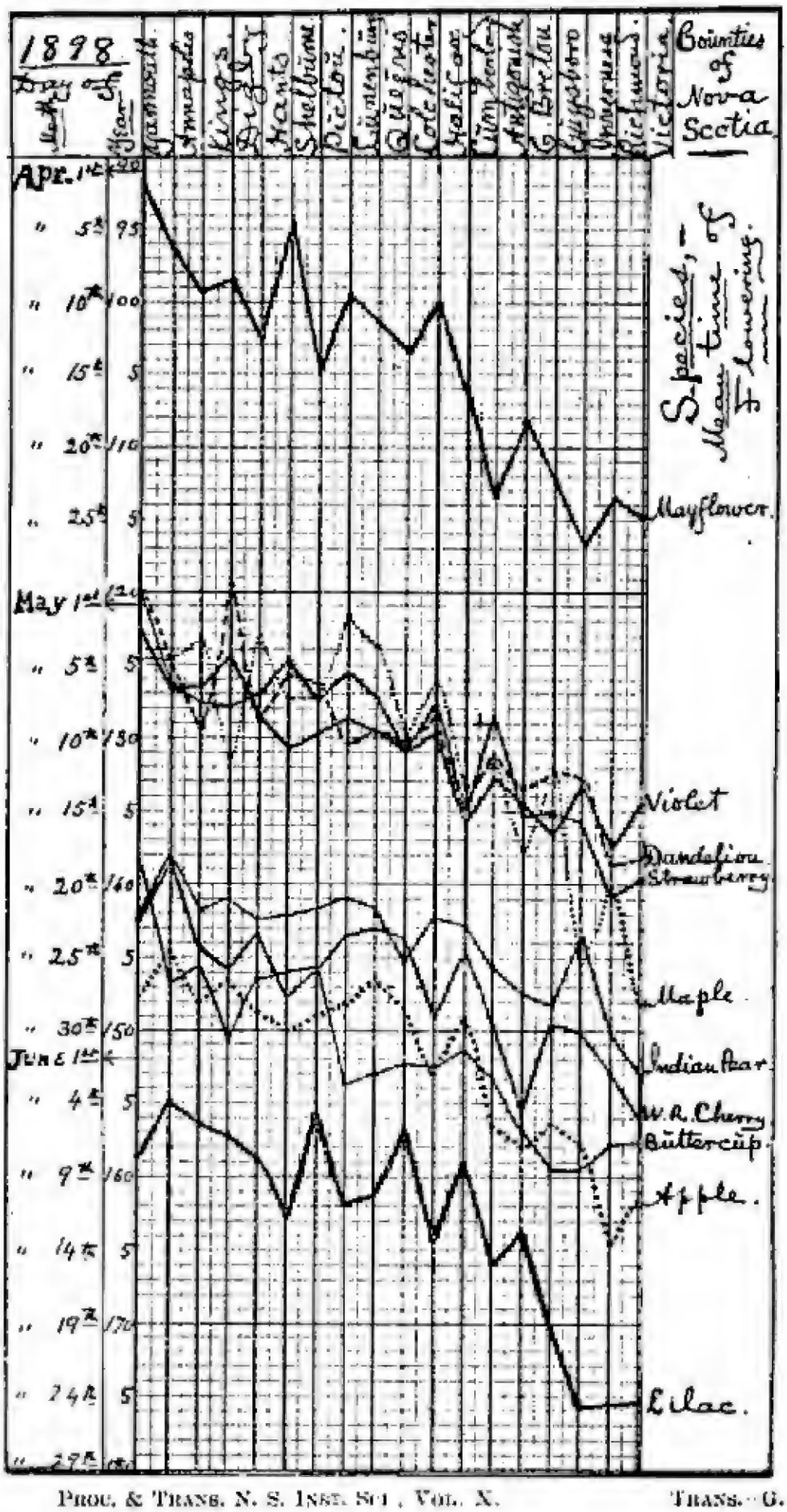

Fig 9 Phenochrons for 1898 (MacKay (1899):97).

CANADIAN PHENOCHRONS, 1902.

OBSERVATION STATIONS—WHEN FIRST SEEN.

Number.	Day of the year 1902 corresponding to the last day of each month. Jan. 31 Feb. 59 March 90 April 120 May 151 June 181 July 212 Aug. 243 Sept. 273 Oct. 304 Nov. 334 Dec. 365	Average dates for Nova Scotia.	Woodstock, N. B.	Charlottetown, P. E. I. (1).	Charlottetown, P. E. I. (2).	Ottawa, Ont.	Beatrice, Muskoka, Ont.	Muskoka, Ont.	Pheasant Forks, Assa.	Blackfalds, Alberta.	Vancouver, B. C.	Average dates for British Columbia.
78b	First snow to whiten ground	313.1	....	293	....	....	....	....	307	300	310	.....
79a	Closing of lakes	316.5	....	....	....	....	....	....	....	311	....	.....
79b	" rivers	354.3	....	345	344	....	....	....	....	312	....	.....
81a	Wild ducks migrating, N	76.3	80	..	....	....	....	....	97	82	....	.....
81b	" " S	295.1	....	....	....	....	....	....	305	300	....	.....
82a	Wild geese " N	70.1	73	60	62	98	....	....	90	80	....	.....
82b	" " S	310.3	....	....	283	....	319	....	307	300	....	.....
83	Melospiza fasciata, North	85.1	88	....	90	74	....	....	120	....	....	....
84	Turdus migratorius "	78.3	79	87	93	74	84	....	82	120	....	.....
85	Junco hiemalis "	79.1	87	....	92	86	67	....	88	....	....	.....
86	Actitis macularia "	124.0	....	....	....	106	....	....	....	....	....	.....
87	Sturnella magna "	107.0	....	....	....	93	....	....	99	....	....	.....
88	Ceryle Alcyon "	121.3	115	....	....	119	....	....	....	....	....	.....
89	Dendroica coronata "	137.2	132	150	....	....	....	....	....	....	....	.....
90	D. æstiva "	119.2	138	....	....	126	....	....	....	....	....	.....
91	Zonotrichia alba "	103.5	129	....	....	115	....	....	....	....	....	.....
92	Trochilus colubris "	146.1	140	....	....	137	....	....	182	....	....	.....
93	Tyrannus Carolinensis "	138.7	138	....	....	140	....	....	147	....	....	.....
94	Dolychonyx oryzivorus "	132.9	138	....	....	133	....	....	....	....	....	.....
95	Spinis tristis "	132.8	108	....	....	130	....	....	....	....	....	.....
96	Setophaga ruticilla "	127.7	142	....	....	130	....	....	....	....	....	.....
97	Ampelis cedrorum "	138.0	9	....	....	74	....	....	....	....	....	.....
98	Chordeiles Virginianus "	126.7	142	....	143	142	....	....	150	....	....	.....
99	First piping of frogs	91.1	103	101	101	84	91	....	104	112	46	.....
100	First appearance of snakes	101.7	....	....	....	94	119	....	117	135	....	.....

Fig 10 Phenological observations in Nova Scotia and Canada (MacKay (1905b): 157).

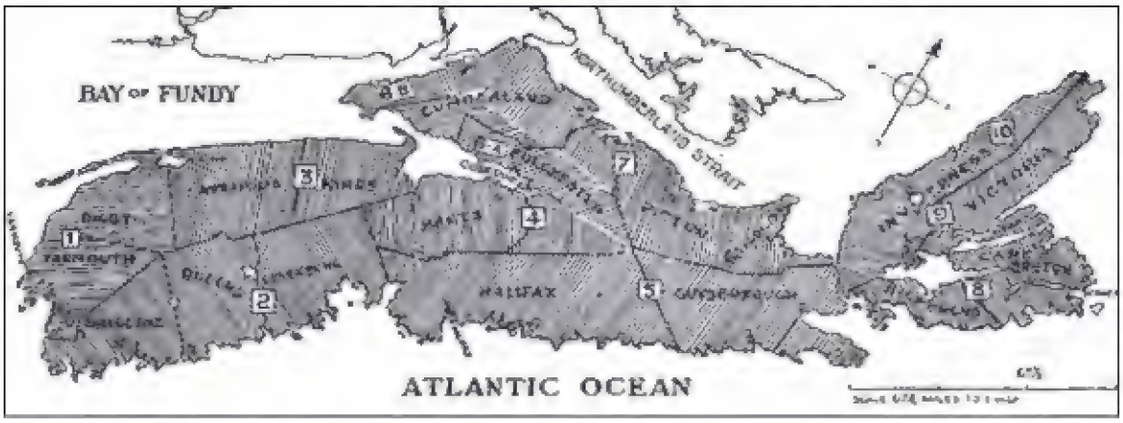

Fig 11 The Ten Phenological Regions of Nova Scotia (MacKay (1912):178.

Experimentalist Ways of Knowing,[18] with new emphasis on the laboratory as the site for cutting-edge knowledge production (Pickstone 2001) especially in new interdisciplinary fields such as biochemistry and atomic theory (Fergusson 1915).

From their respective influential vantage points, Lawson, MacGregor, and MacKay not only promoted advanced science teaching in Nova Scotia through firsthand laboratory experience, which Lawson recognized as "a great, if somewhat silent change" in the universities (Lawson 1888:xxiii). MacGregor and MacKay also worked to bring the laboratory experience into Nova Scotian secondary schools. While the similarly named educator and administrator Alexander McKay's (1841-1917) presidential address in 1898 expressed regret that, despite these efforts, "experimental work [seemed] almost wholly neglected" there (McKay 1899; Yorke 2003), his superior, AH MacKay, reported progress on this front only three years later: "Throughout the province several of our county academies or high schools have better laboratories for proper science teaching than had our best colleges not many years ago; and some of the teachers are more competent than many of the good old college professors" (MacKay 1902b).

In the same address, however, MacKay recorded the NSIS's mixture of pride and regret at MacGregor's recent departure from Halifax, to succeed PG Tait in the prestigious Chair of Natural Philosophy at the University of Edinburgh. MacGregor's reputation as "a very expert experimental investigator" included recognition that "with his skill and ingenuity he made anything into apparatus, and made a little go a long way, and made it give him precision too," under physically

[18] Experimentalist Ways of Knowing aimed to "transform" nature (Wynn 2007: Part 5) through synthesis and invention, predominantly in the laboratory (Pickstone 2001: Part 3).

challenging conditions that put later, better-equipped generations to shame (NSIS 1919b:lxxxii). A measure of MacGregor's achievement through the NSIS in this regard may be found in the fact that when he had applied to succeed Alexander Johnson (1830-1912) in McGill University's Chair of Natural Philosophy in 1890, McGill instead preferred a candidate trained in the older Cambridge mathematical tradition[19] (Gingras 1991:20). At Edinburgh a similar struggle to introduce laboratory work into science teaching preoccupied MacGregor for the rest of his career, and may have helped to cut it short (MacKay 1902b; MacGregor: a Scottish tribute 1913; Knott 1913). His unexpected and untimely death of heart failure in 1913 quite naturally intensified the retrospective mood that marked the end of the NSIS's first half-century.

HEADWINDS

Among recurrent themes, an essential tension between theoretical and utilitarian goals[20] – between specialized and general interest – in science, which had characterized the NSIS since its founding (Lawson 1896:x-xi), remained a source of concern. One repeated response was to offer the kinds of popular lectures that attracted large audiences in other jurisdictions (MacGregor 1890a:190-1; MacKay 1905a:v; Mackay 1912a:vii; Bishop 1912:xxv). Yet neither these efforts nor the admission of women as Ordinary members from 1895 substantially increased NSIS numbers (NSIS 1896:xvi). The longstanding problem of the NSIS's inaccessibility to members who resided outside of Halifax also found a hopeful response in the establishment in 1901 of an offshoot centred at Acadia College in Wolfville; in this first iteration, however, the group ran out of steam by 1904 (MacKay 1902b:lxxxviii-lxxxix; Haycock 1902; NSIS 1908:ix; Piers 1915:lxxiv). Besides the palpable effects of the RSC, the appearance of specialized regional professional societies, including the Mining Society of Nova Scotia (1892) and the Nova Scotia Society of Engineers (1906), also continued

[19] MacGregor's innovative abilities in studies of ionization theory (much like those of Ernest Rutherford in atomic theory at McGill a few years later) rested with his affinity for laboratory apparatus; in contrast to his authoritative confidence on this front, he believed that his own mathematical insight and training were inadequate (MacGregor: a Scottish tribute 1913:5-6; Mackenzie 1913:lxxxii).

[20] AH MacKay traced this dichotomy back to the difference between ancient Greek and Egyptian outlooks on nature, respectively (MacKay 1902b:lxxxix-xc).

to chip away at NSIS memberships as well as at the *Proceedings and Transactions* (Mackay 1912a:iii; Bishop 1912:xxiv; Piers 1915:lxxiii).

MacGregor had, furthermore, opened the vexing question of how to meet the skyrocketing costs of laboratory research. His RSC committee report in 1885 recognized "private beneficience" as the only realistic source of funding in a world of cash-strapped public institutions (MacGregor 1886a:xli) whose leaders had hardly begun to imagine taxation levels on the scale of scientists' rapidly growing wish-lists. When the Royal Society of London invited financial contributions to its Victoria Research Fund in 1897, the NSIS regretted that, since Nova Scotia's "industries have not yet reached the stage in which the advantages of scientific research become manifest," it could do no more than pass the word along to those in a better position to offer funds (NSIS 1897). As the need for laboratory equipment intensified, it was all the NSIS could manage to offer grants of $25-$50 to scientific research students in 1912-13 (NSIS Council Minutes 1912:18 July and 4 October; NSIS 1915:xlvi). Moreover, it was also becoming painfully apparent that the "collection of partially catalogued, somewhat inaccessible reports of scientific societies" that resulted from the NSIS exchanges could hardly "be said to constitute such a scientific library as the majority of workers need, however useful it may be to those engaged in original research" (McKay 1900:xxxviii). What little hope there was of government support for research focused on projects initiated by the BAAS and other external influences. In response, NSIS members worked to get Nova Scotian scientists and students actively involved in the federally-funded Marine Biological Laboratories that began work along the Atlantic coast in 1899 (MacKay 1902b:xcvi-xcvii; MacKay 1905a:iv-v; Hubbard 2006:chapters 1-2).

A. Industrial and/ or Conservationist Research?

With government funding even for existing projects in such short supply – the loss of the NSIS provincial government grant (apparently in an oversight) in 1907 turned out to be anything but temporary – the achievements of full-blown industrial research in both Germany and the United States soon illuminated the NSIS's horizon. In 1906 NSIS president FWW Doane explained how "some of the best research work of to-day is being guided by business corporations," assuring his audience that the "purely scientific spirit" continued to guide scientists so engaged (Doane 1908:v). Two years later Ebenezer Mackay, Dalhousie's first honours graduate in chemistry (1886) and a research

PhD from Johns Hopkins University, interpreted (again overly optimistically, as it turned out) Nova Scotia's Technical Education Act in 1907 as an indicator that "the value of research work is appreciated in industrial circles," so that "our Institute, no longer obliged to go into the highways and hedges in order to compel men to come and fill up its programme, will be embarrassed with the wealth of papers at its disposal" (Mackay 1912a:l-li). MacKay's presidential address in 1910 minced no words regarding the decisive role of science in a modern industrial society. After explaining recent achievements in the chemical synthesis of organic compounds, especially in Germany,[21] He warned his NSIS audience that:

> It requires no prophet to foretell the conclusion of the story: the industry of indigo production [and with it the production of chemical dyestuffs, fertilizers, explosives, and other crucial hydrocarbon-based syntheses] will pass from the banks of the Ganges to those of the Rhine. And the moral is equally plain. It is the country that is most successful in making science not merely the occasional adviser of the industries, but their ally and confidant, that will be victor in the contest for industrial supremacy (Mackay 1912c:xviii).

On a competing front, as time would soon confirm, the role of science in the conservation of Nova Scotia's natural resources, especially its forests and fisheries, also took on new urgency. Ever the activist, AH MacKay used his role as Nova Scotian vice president of the Canadian Forestry Association to facilitate a joint meeting with the NSIS in 1904 (NSIS 1906), followed by the appointment of an NSIS committee on forestry. MacKay served an analogous role on the board of the Marine Biological Laboratories, whose mandate he interpreted in terms of research to conserve the Atlantic fisheries (MacKay 1902b:xcvi-xcvii; MacKay 1905a:iv-v). Ebenezer Mackay followed up with the force

[21] In 1909 Mackay also cautioned his NSIS audience that recent "epoch-making work" in atomic theory did not yet justify the "evil consequences" of assuming atoms' actual existence. Ernest Rutherford's recent announcement, however, "that he had obtained a direct experimental proof of the existence of atoms" led Mackay to concede that perhaps "atomic theory, unlike the systems that have had their day and cease to be, is to abide with us as a permanent utility" (Mackay 1912b). The *NSIS Proceedings and Transactions* were already publishing papers on experimental research in Dalhousie University laboratories on radiation.

of his presidential cudgel in 1908, calling the NSIS to public service on these important issues as its natural responsibility:

> Where important natural resources are being wasted, it is the duty of a scientific society such as the Institute to do all in its power to arrest the evil. The Institute is the only scientific society in the province and as such should be the official exponent of scientific opinion. It should be able to create what may be called a scientific public opinion powerful enough to make itself felt. It is as true now as in the days of the wise king that "Where there is no vision the people perish." In such a case as the present, it is for men of science to supply[22] the lack of vision (Mackay 1912a:li-lii).

In the same vein, Mackay called upon the NSIS to sound the clarion call of "enthusiasm" to engage farmers, fruit-growers, fishermen, and others who worked on the scene, as early-warning observers of infestations and related conservationist issues (Mackay 1912c:v-vi). For all that Sir Wilfrid Laurier's Liberal government's establishment of the Canadian Commission on Conservation in 1909 represented an encouraging initiative, the Commission's mere fact-collecting powers, argued a far-sighted DB Fergusson in his 1913 presidential address to the NSIS:

> Could be vastly extended to providing endowment for research and founding establishments like the Kaiser Wilhelm Institut in Germany. If civilized nations could see the absurdity of settling ethical issues by destruction of cellular tissues, large sums of money would be available for research into conserving the national resources which we use at present, and tapping those going to waste around us. We might then feel less ashamed of what future generations will think of the manner in which we squander their birthright of mine, field and forest (Fergusson 1915a:cxxi-cxxii).

[22] Mackay's use of the word "supply" here, as in filling a gap, has gone out of fashion and suggests the opposite of his meaning.

The NSIS thus entered the 20th century with some forewarning of what its second fifty years might bring, but no inkling yet of how deeply some longstanding assumptions would soon be called into question. A comparative "wealth of facilities" had not kept up, let alone surpassed, "the output of the old strenuous days when we met in the poorly lighted, badly seated, and primitively warmed and ventilated museum" where its 24 founding members had first assembled. A periodic pruning of membership lists when payments fell into arrears also showed Ordinary memberships tending downwards to about 75, raising questions about how best to assess the real state of the Institute's well-being (Mackay 1912c:ii-iii). How, then, to continue its struggle to nurture "the development of the scientific cult of to-day" (Bishop 1912:xxiv) in the face of an increasingly splintered constituency (Mackay 1912c:v)?

Recurring NSIS tensions between aims and audiences – between the determination to publish original scientific work and the wish to engage as many Nova Scotians as possible – intensified with the unprecedented series of international crises that plunged the Institute – along with the rest of the country – into war, economic instability, and war again. While the force of circumstance limited available options, the Institute continued its efforts to navigate between the Scylla of falling behind the science of the times, and the Charybdis of becoming irrelevant to its place of origin.

B. Forced Hands

The outbreak of the Great War in 1914 altered important conditions under which the NSIS operated. Without its provincial government grant, the Institute faced increasingly dire financial circumstances in a situation about which it could say or do very little. Exchanges with most of Europe also ceased abruptly. The war not only curtailed important European research; it also cut off from North American research and industrial production indispensable chemical products under German monopoly, including potash, synthetic dyes, and even precision glass for periscope lenses (Fergusson 1915b:iv-v; Fergusson 1916:xvii-xix).

Like other scientists elsewhere, the NSIS soon forged its initial shock at the grave results of Allied failures to heed its earlier warnings, into hope that the British and Dominion governments' rude "awakening" to "the value of science and scientific research" would at last become "complete and permanent" (Fergusson 1916:xvii-xix;

NSIS 1916:xxiii). The establishment in 1916, after German poison gas attacks on the front had begun, of British and Canadian Honorary Advisory Councils for Scientific and Industrial Research led DF Harris to assure the NSIS in his presidential address that year that:

> Appalling beyond human comprehension as are the evils of this insanest of all wars, yet it cannot be denied that some measure of good is emerging distinctly from the welter. It is not too much to say that for the first time in the history of the British Empire, science is coming into her own. It is no doubt humiliating to have to confess that it was the misapplied science of our enemies which demonstrated to us how inferior was the place we had given science in our own national life. The land that produced Roger Bacon, Napier, Gilbert, Harvey, Newton, James Watt, Jenner, Faraday, Darwin, Kelvin, and Lister had to be shown by the exponents of science prostituted that science was nevertheless worth cultivating *for its own sake* (author's italics; Harris 1918:xxxvi).

In practice, however, an NSIS suggestion to the Minister of Militia and Defence in response to Canada's Military Service Act in 1917, that "technically trained men as may be enlisted be drafted into that particular branch of the service for which they are most nearly fitted by their training and experience in civil life," elicited little more than polite assurances of "due consideration" (NSIS 1919a:lxx). War's end brought a more militant NSIS resolution that, "with a view to the future protection of the Canadian chemical industry" and "before the signing of peace," the federal government ought to "empower a Canadian foundation company to control enemy patents registered in Canada" (NSIS 1919c).

Wartime also left its imprint on the NSIS's regular routine. Research papers for presentation dwindled to a trickle, raising suggestions once again about offering popular scientific lectures, at least to wait out the storm (NSIS Minutes: 28 March 1918). While members had by 1914 already noted such a predominance of papers in physical sciences that presentations in other fields "met with a hearty welcome" (Fergusson 1915b:ii), this trend persisted well into the postwar years, with research on the production of synthetic dyes and potash, and mapping

Nova Scotia's distribution patterns of naturally occurring chlorine as "isochlors" (Creighton 1919; Vickery 1919; Whyte 1921; Munro 1923).

Moreover, discussions about whether to continue limiting the *Proceedings and Transactions* to Nova Scotian topics whenever possible resulted in a 1917 resolution that the publication be open only to scientists working in Nova Scotia (NSIS 1919a:lxx-lxxii). As Murphy's Law might have it, an interesting dilemma resulted with the arrival in 1919 of a paper from a longstanding Corresponding member, Major JH Barbour (1873-1944) of the Royal Army Medical Corps (stationed in Halifax, 1903-1905), who had managed to botanize during his wartime service in the French countryside and now offered a paper on the subject for comparative purposes. The upshot, after the NSIS Council agreed to read the paper at the next Ordinary meeting, included formal decisions to give priority in the *Proceedings and Transactions* first to the natural science of the maritime provinces and, secondly, to other scientific work by "active members residing in Nova Scotia,"[23] and thereby to decline to publish Barbour's paper (NSIS 1919a; NSIS Minutes 2 January, 8 November, 13 October 1920).

C. Boom and Bust

The return to peacetime in 1919 lent old themes new twists. Inflation meant rising costs, labour disputes, and a level of financial concern for the *Proceedings and Transactions* that forced the NSIS to consider publishing only abstracts of papers presented at its meetings. It also emboldened successive NSIS Councils to remind the provincial legislature that its annual grant had fallen by the wayside in 1907, and never been restored. On that front it finally succeeded in 1927, regaining sufficient funds to update the Provincial Science Library but leaving the *Proceedings and Transactions* to cut back pages if more revenues could not be secured (Johnstone 1928:xxii).

It is difficult to assess precisely the war's impact on NSIS memberships, because during that time annual lists were not revised to remove names with unpaid dues. While Ordinary memberships began once more to climb noticeably in 1919 (NSIS 1920:xxi; NSIS 1921:xxix), Corresponding memberships took longer to recover, then declined

[23] Barbour had been stationed in Halifax, 1903-05: http://www.bonhams.com/auctions/20810/lot/245/, accessed 30 March 2014. This criterion was widened again in 1926 to put the onus on the Council, so that any paper read first before the NSIS could be deemed eligible to appear in the Proceedings and Transactions (NSIS Minutes of Council 1 November 1926).

precipitously during the Great Depression of the 1930s (Fig 12) (King 1940:47): the Council resolved as late as 10 April 1922 not to resume exchanges with Russia, Germany, Austria, and Hungary for the time being. It amended this decision on 4 December 1923, restoring German, Austrian, and Hungarian societies to the NSIS mailing list (with the Recording Secretary, Harry Piers, dissenting) but deleting all Russian [now Soviet] institutions.

The decisive factor during this period was the establishment of the National Research Council of Canada [hereafter NRC] as a permanent institution in 1923, with its *Canadian Journal of Research* following in 1929. The NRC entrenched Experimentalist Ways of Knowing in Canada (as happened elsewhere) more deeply than ever during the 1920s and 30s, to the point of denying federal funding for natural science fieldwork in favour of applied and especially industrial research (Ainley 1988). A continuing chronic shortage of research papers dismayed the NSIS as a failure in its "chief aim" (NSIS 1923:I; Ritchie 1926a:xxxi), with the Council asking its members to report "the results of all scientific work they might be engaged upon, to be published in abstract, or in some cases in full." Despite some success, the editors of the *Proceedings and Transactions* made frequent adjustments in order to carry on – not only against increasingly numerous specialized competitors, but also in the face of printers' strikes, fires, and lost papers that delayed issue after issue during the 1920s, through no fault of the Institute – but inclining potential authors even less to submit papers (NSIS 1926b:xxiv-xxv; Ritchie 1926b:viii; McIntosh

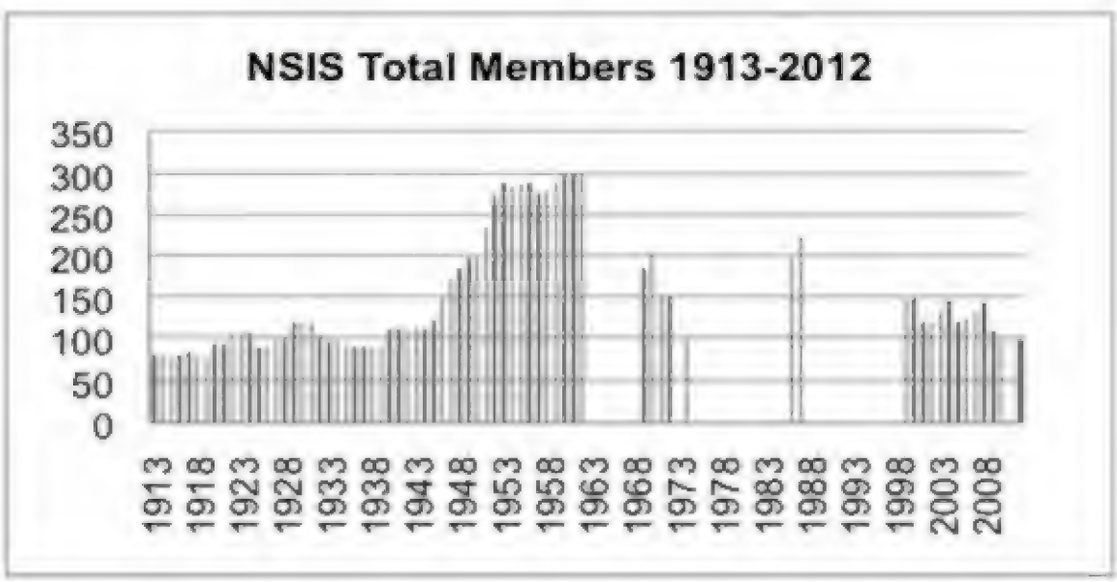

Fig 12 NSIS Total Membes, 1913-2012.

1929:xxxv; (Nickerson 1925:xx; Johnstone 1927:xiii; McIntosh 1929:xxxiv-xxxv).

A committee first appointed in 1919 to identify ways to "further the cause of science in a more popular and general way" (NSIS 1920:xxi) became a kind of *ad hoc* standing committee during the 1920s, re-appointed annually to develop new ideas. The first, an annual series of popular science lectures that sometimes attracted large audiences, challenged the NSIS to learn both to advertise its activities more effectively as well as to balance its programme with both physical and biological sciences if it hoped to remain the "tremendous factor in the scientific, industrial and economic development" of Nova Scotia that it seemed to have been in JG MacGregor's day (Nickerson 1925:xx; NSIS 1925; NSIS 1926a:xxii; Ritchie 1926a:xxxi, xxxiii).

The 1926 committee, still dissatisfied with attendance, hit upon the idea of organizing a science exhibition "to stimulate a more widespread interest in pure science and it's [sic] possibilities." With cooperation from the local universities, the College of Pharmacy, the Technical College, and the Atlantic Experimental Station for Fisheries – and support from the local radio station and public transportation – the resulting exhibits and demonstrations succeeded "beyond the expectations of its promoters" in attracting at least 4500 visitors, leading the NSIS president to dream wildly of tripling memberships to "at least 300" (Johnstone 1927; NSIS 1926c). A still larger exhibition in 1928 attracted corporate sponsors and 6000 visitors, leaving its harried NSIS organizers (although not the NSIS executive) unwilling – with expenses of $26.35 to pay from NSIS funds – to plan another such event (NSIS 1929a; McIntosh 1929:xxxv-xxxvi; McIntosh 1932: 15; Leim 1935:287). Nor did the remarkable power of scientific demonstrations to attract larger audiences go unnoticed in these experiences (Henderson 1939b:25).

With new memberships during these years nevertheless stemming not from the general public, but rather from new colleagues in Nova Scotian universities, the NSIS president in 1929 reiterated its grand aim "to have in its Transactions a record of all original work done in Nova Scotia." Opening up the prospect of occasional meetings outside of Halifax, the Council sought to engage Associate members to report "any work of a scientific nature of provincial importance" in their respective institutions. It also inaugurated Student memberships (at reduced cost and without a vote) in 1930, adding 21 original

Student members[24] to an overall list that continued to hover around 100 (McIntosh 1929:xxxv; NSIS 1932:17; Young 1933a:68-69; Young 1934:215-216).

It was on behalf of its research-oriented constituents that the NSIS now played down popular lectures, instead undertaking two new endeavours during the 1930s. In 1934 it came to the Council's attention that the new *Union List of Scientific Serials in Canadian Libraries* cited no Canadian libraries east of Montreal. An NSIS survey of regional libraries for lists of their scientific periodical holdings became the basis, with NRC funding, for the NSIS's *Catalogue of Scientific Periodicals in the Libraries of the Maritime Provinces* (1936)[25] (NSIS Minutes of Council: 29 January, 12 February, 30 April 1934; 22 April, 30 September, 9 October 1935; 13 January 1936; NSIS 1938:287; NSIS 1936b).To attract more research papers, the Institute in 1937 also began offering travel funds for presenters from outside of Halifax (Henderson 1939a:441).

In response, one member's resignation in 1934 to protest the NSIS's heavy emphasis on original research once again opened the familiar chasm that the Institute could never really close. A set of resolutions reaffirming the principles of open discussion in the Institute's mandate silenced an open disagreement over what level of questioning constituted "fair play" toward papers that some members deemed not sufficiently original or scientific (NSIS Council Minutes: 9 October 1934, 30 September 1935). Not far behind festered a long-simmering chagrin articulated by Harry Piers, by then one of the oldest NSIS members and still Recording Secretary, that – despite a recent rise in research papers on biological topics (Young 1934:216) – papers "on the lines of natural history or faunistic work" in Nova Scotia that should "logically" be sought out for the *Proceedings* had instead become rarities on NSIS programmes. Moreover, a revealing Council discussion across two committees in 1931 seemed, in typical Experimentalist form, to equate natural history with a dilution of "real" science better suited to an occasional popular lecture[26] (NSIS Minutes of Council 1931:26 October, 5 November; Leim 1935:286).

[24] Scientific research could be dangerous work: while it was bad enough when one NSIS member drowned while conducting biological research in the Gulf of Mexico in 1929, it was even worse when an original student member was killed in a chemical laboratory accident two years later (NSIS 1929b; NSIS 1932b).

[25] Future supplements of the *Union List* no longer ignored maritime libraries (NSIS 1963:203).

[26] This assumption was repeated in the NSIS Council meeting on 13 November 1950.

After repeated presidential rebuttals that the apparent disappearance of natural history:

> Is the fault, not of the officers or council, but of our naturalists. It is hardly necessary to say that contributions from them will be welcomed in the same spirit as those received from our physicists or chemists (McIntosh 1932:15; see also NSIS Minutes 1930:8 December).

Piers utilized his own Presidential Address in 1936 to offer "Suggestions for Future Revisional Work in the Natural History Field." Citing recent examples, he noted in particular "the present need of thoroughly revised or new working-lists of our fauna and flora," especially "in the light of recent additions as well as progress in nomenclature" to which Nova Scotian fieldwork still had important contributions to make (Piers 1938:283-285).

The NSIS decision to mark its 75th anniversary in 1937 by inviting the NRC president, Major-General AGL. McNaughton (1887-1966), to address the Institute on "The Organization of Research in Canada" instead reaffirmed the deeply entrenched order of the day: science meant laboratories, research meant industrial efficiency, and Soviet Russia's state-driven industrial applications of science now seemed to offer the shining example of the way forward for Canada. "If we fall behind in the struggle" to keep up, McNaughton warned an audience of about 250 people, "we face disaster just as certainly as did the tribal peoples of early history" (McNaughton 1938; 218-220, 223, 228-231).

D. Unexpected Ironies

McNaughton's military swagger, forged in the bitter lessons of the Great War's darkest days and continued as he fought bitterly to secure federal funds for NRC laboratories, found renewed power as Canada entered the breach once more in 1939. What one NSIS president called "the crazy, screaming vortex of a global war" reaffirmed the need for constitutional amendments to NSIS by-laws to ensure flexibility "to meet changing conditions" (King 1941:48; Bean 1946:4). This time, membership numbers – even with new potential among Halifax-stationed servicemen – fell steadily as NSIS members were seconded for government service, assigned to overseas military service, or, still worse, killed in action. Shattering once again the Institute's hard-won exchange networks, total war also altered once again the balance of

research topics as nothing else could do, this time imposing blackouts on presentations in physics, chemistry, and the fisheries because of their strategic importance. The result was fewer papers overall, but a greater proportion in biology and related fields, with growing interest in genetics as "the most outstanding feature in the development of biology during the present century" (Gates 1941:127; King 1941; Bean 1942:291; NSIS 1942).

Regional research facilities and their staffs and students multiplied after war's end in 1945, boosting NSIS memberships and attendance at meetings to unprecedented heights. These positive developments were especially "interesting," as the NSIS president, FR Hayes, observed in 1946:

> In view of the complete absence of innovations designed to make the Institute into more of a social organization, or to dilute or popularize its scientific reports. Living as we do in the golden age of advertising, it is a matter of satisfaction to discover that an organization can flourish when it has nothing to offer except solid worth (Hayes 1948:13).

In particular, the Institute welcomed the Defence Research Establishment Atlantic (DREA) in Dartmouth in 1944, which became part of the national Defence Research Board in 1947; the Nova Scotia Research Foundation in 1946, which absorbed some of the burden of maintaining and expanding the Provincial Science Library; the Faculty of Graduate Studies established at Dalhousie University in 1949; and the NRC's Atlantic Regional Laboratories in 1952, all raising high hopes that NSIS membership numbers would rise accordingly. By 1948, much hard work had also restored prewar levels of NSIS exchanges. This postwar optimism reaffirmed the value of the published *Proceedings*,[27] despite ongoing challenges sustained by their dedicated editors; and of fully integrated NSIS meetings, despite informal calls once again for sectional divisions with separate – and perhaps even concurrent – discussions of ever more specialized research topics (Coffin 1950:37; Weld 1951; NSIS Minutes 1952: 20 October; Weld 1953; Dingle 1962). As one president wondered, were these grumblings not "expecting too much of such an Institute as ours in an age when it is becoming

[27] "*Transactions*" had been dropped from the title with the appearance of Volume 19 in 1935. The *Proceedings* were also earning recognition for their historical value (Aldous 1960; Fergusson 1962: 243; NSIS 1963:204).

difficult for biologists to consult with physicists, and physicists tend to speak only with God?" (Dingle 1962).

With an unprecedented membership of 200 still rising in 1950, the postwar NSIS faced the unfamiliar dilemma of either becoming "unwieldy," or "losing ground" if it did not continue to expand in proportion to the "rapidly increasing" scientific community around it. Either way, the Institute soon replaced its habitual "concerted drive for new members just for the sake of it," with concern to persuade a greater proportion of almost 300 members in 1953 to attend meetings and to volunteer research papers, an area in which the expected influx never materialized (NSIS Minutes: 26 October 1953). One response was finally to schedule meetings in regional research centres, including those conducting agricultural research in Wolfville, Truro, and Kentville, followed by the reorganization in 1952 of the NSIS Annapolis "Valley Chapter" at Acadia University, with a healthy 35 charter members and counting (Weld 1953; Cameron 1954; Chute 1955; NSIS Minutes of Council 7 Nov 1955; Smith 1958; Dingle 1962).

Despite the reminder by president JG Aldous in 1958 that "by 'scientific' I mean seeking by experiment, the answers to questions concerning natural phenomena" (Aldous 1961), the early 20th century's pervasive logical positivism was giving way, at least at its edges, to a broader range of scientific sensibilities. With government research laboratories "primarily intended to assist local industries and the development of the Atlantic region generally" under a narrow Experimentalist understanding of industrial research that urged even colleagues working on "fundamental" problems to choose topics with obvious applications to industry (Dingle 1963:202), new approaches to biological research renewed the need for – and restored recognition of the scientific validity of – evidence from the field as a "disciplinary marker" (Nielsen, Harbsmeier, and Ries 2012:9).

For example, the Valley Chapter reinforced a growing cluster of NSIS members whose research in Nova Scotian ecology would have pleased Harry Piers. Ecology, which studies organisms in relation to their environment, refashioned earlier Natural Historical and Analytical approaches to the natural world (Somers 1876; Lindsay 1876) by applying recent insights from biological, physical, and social sciences: while working within the framework of Experimentalist Ways of Knowing, it nevertheless required regional fieldwork. Besides the pioneering contributions to this transition by W.F. Ganong (Ganong 1901, 1904, 1913; Wynn 1981), a note from the Ecological

Society of America (established in 1915) had prompted the NSIS to appoint a committee in 1917 to consider "the preservation of areas of peculiar interest for ecological study" (NSIS Minutes of Council: 30 November 1917), albeit with no apparent follow-up. As wartime crises took priority, the ensuing heyday of industrial research had by 1921 ensured the quiet demise of the Canadian Commission of Conservation, overshadowing both ecological and conservationist concerns during the decades that followed (Girard 1991).

Yet highly praised ecological studies did begin to reach NSIS meetings and appear in its *Proceedings* during these years (Hayes 1926ab; Piers 1938:283-285; Pettingill 1939; King 1940:48; Dore and Roland 1942). Nova Scotia's provincial botanist, AE Roland (d. 1991) of the Nova Scotia Agricultural College in Truro, pointedly verified Harry Piers's earlier concern, explaining in 1941 that "During the last thirty years the local botanists have been almost entirely inactive," leaving the field to "outside specialists" from the United States and Europe (Roland 1941). Roland elaborated several years later: while regional work on Nova Scotian plants had actually been accruing for decades at the Provincial Museum, it all too often remained unpublished (Roland 1946).

Roland's "Flora of Nova Scotia" took up the slack by occupying an entire oversized issue of the NSIS's *Proceedings,* which sold out several reprint editions, and continues to do so. This new publishing phenomenon revived the NSIS's original understanding that its scientific importance rested precisely in its regional contributions to larger scientific problems (Roland 1946; Weld 1951:51; Chute 1956:40). Other ecological studies repeated this pattern, in several instances again comprising entire issues of the *Proceedings* that attracted sufficient attention to require reprints – and providing the NSIS with a welcome new source of income (Gorham 1948; Livingstone 1953; Ferguson 1953; Erskine 1954; Pickett 1956; Archibald 1958; Bousfield 1958; Vickery 1961; Loucks 1962). A similar series emerged from the Valley Chapter, originating in the Perry Biological Laboratories and other Departments at Acadia University (Bentley and Smith 1956; Webster 1956; Erskine 1958; MacLellan 1958; Bentley and Smith 1960; Moore 1963).[28] As a result, the Institute's centenary celebrations in 1962 elicited appreciative remarks from the lieutenant governor, Major General EC Plow (1904-88), who singled out its "extensive

[28] These represent only a sampling of ecological papers from both the Halifax and Wolfville meetings.

publications on the flora and fauna of the Province in recent years" (NSIS 1964:262).

These celebrations also featured keynote lectures by two distinguished scientists whose work reflected broader issues of popular interest and concern: HB Newcombe of the Biological Branch, Atomic Energy of Canada, a pioneer analyst of the effects of radiation on human health, spoke on "Man and His Genes" to audiences in both Halifax and Wolfville; and Sir Bernard Lovell, Professor of Radio Astronomy and director of the Jodrell Bank Experimental Station, University of Manchester, drew 600-800 people to his talk on "The Exploration of Outer Space" (Archibald 1964:18). The NSIS also made good its earlier intention, commissioning a scholarly NSIS history by CB Fergusson, the provincial archivist, who enjoyed access to the NSIS Minutes as far as 1936[29] (Fergusson 1962; NSIS Minutes of Council 1956: 12 March).

CLEAR(ER) SKIES

The NSIS thus embarked on its second century with every reason to lead with its obvious strengths, even as some members continued to conflate ecology with natural history (Masson 1968a:253-255; Masson 1968b). The upshot was an impressive succession of thematic and monographic[30] *Proceedings* dedicated to international ecological and oceanographic[31] conferences held in Halifax (Volumes 27, 42, 43); to landmark events such as the Atlantic Regional Laboratory's 25th anniversary in 1977 (Volume 28); and increasingly to environmental[32] topics (Volumes 27, 30, 42) – as concern over the oil crisis, pollution, genetic engineering, and the industrialized over-harvesting of natural resources gave traction during the 1970s to a burgeoning environmental movement in Atlantic Canada, and in Canadian society more generally[33] (Cameron 1974:92; Wynn 2013:248-253).

[29] More recent historical analyses walk a tightrope without a balancing pole, with no NSIS Minutes entrusted to archival care after 1958, despite promises in 1999 to "complete" the NSIS's archival record (Niven 2001).

[30] Ian MacLaren's "The Birds of Sable Island" demonstrated the extent to which the *NSIS Proceedings* had become an important historical source of ecological and environmental information (MacLaren 1981; see also NSIS 1992:148).

[31] Dalhousie University's Institute of Oceanography had been founded in 1959.

[32] Dalhousie University's Institute for Environmental Studies had been founded in 1974.

[33] By 2003, the NSIS distinguished Environmental from Life and Physical Sciences as the categories for its Student Science Awards (NSIS 2004).

A. Fundamental Questions

Not far behind, as always, were uneasy members who expressed "real concern" for "the status of its Journal." "We have," argued the NSIS president in 1962:

> Never had a very clear cut idea about the role it should fill. It had been used recently for recording rather long detailed studies of local flora and fauna, studies that would probably not be received elsewhere because of their length and limited interest. This is a very useful thing to do and a real purpose has been served; articles of this sort should be published in the future in ever increasing numbers. But the time may be upon us when we should widen the scope of our acceptances ... if we manage to solve our financial problems (Archibald 1964:20-21).

Unexpected ironies continued, first because the Council used the *Proceedings'* recent focus on regional studies to justify its (successful) application for a quadrupled government grant (from $500 to $2000) on an annual basis to keep the journal afloat; and secondly, because papers on other topics were – still – simply not forthcoming (Roland and Smith 1966 and 1969; McCarter 1966:240; McCarter 1968:248). Stagnating membership numbers, at about 100 out of a regional research community of some 800, declining attendance at regular meetings, and vanishing Student memberships moved the Council in 1965 to appoint a committee "to consider the role of the Institute in the scientific community," with no clear answers arising during a period of repeated inquiries as to the NSIS's basic purposes. These discouraging realities became dire when the provincial government unexpectedly reduced its annual grant to $500, pressing the NSIS once again to reaffirm the regional – and increasingly lucrative – focus of the *Proceedings*[34] (Masson 1968a:253-255; Masson 1968b; NSIS 1971; Blanchard 1974; Wangersky 1977).

While others expressed frustration with the NSIS's fundamental dilemma, how best to "serve science effectively" in the face of the fundamental fragmentation that had become "a fact of modern life"[35]

[34] The financial burden was eventually shared by NSERC, Acadia and Dalhousie Universities, the Technical College, and the Nova Scotia Museum, which showed itself a staunch ally of the NSIS in myriad ways during this period (Vining 1981; Forrest 1988).

[35] The British scientist and author CP Snow (1905-80) had famously warned in *The Two Cultures and the Scientific Revolution*. (1959) that the failure of scientists and humanists to communicate in modern society precluded the solution of important problems.

(McCarter 1968:248), President HBS Cooke's imaginative effort in 1968 to "get back to the kind of atmosphere which was created for people in a wide variety of disciplines" by the NSIS a century earlier, led him to apply the kind of insight that critical theories in philosophy and sociology[36] had to offer. What the NSIS needed, Cooke suggested, was a "modern interpretation of the objectives for which the Institute was founded":

> Just as many of the amateurs of that time were laymen in the strict sense of the word , yet were learned in one branch of knowledge in proportion to the scientific knowledge of the time, so today *the average scientist is a layman in all sciences other than his own*. It seems to me that we should concentrate very much more on well-organized interdisciplinary discussion which might try to break *across the artificially created barriers of narrow specialization* (author's italics; Cooke 1968:268-269).

Indeed, recent meetings had already seen animated audiences engaging in exploratory discussions that were led by specialists who could make cross-disciplinary connections. Besides the habitual focus on "the machinery of putting scientific knowledge to use in society," which remained important, it was becoming clear – with the new scholarly disciplines of history and philosophy of science emerging – that "The philosophical aspects of scientific endeavor should not be neglected" (Dyer 1968:263). Along these lines, 110 people in 1971 attended an informed critique of Canada's science policy by the distinguished ecologist and former NSIS president FR Hayes (1904-82), who had founded Dalhousie's Institute of Oceanography in 1959, and chaired the Fisheries Research Board (1964-69); Hayes expanded his influential critique in *The Chaining of Prometheus: Evolution of a Power Structure for Canadian Science* (1973) and went on to establish Dalhousie's Institute of Environmental Studies in 1974.

In keeping with this new critical spirit – in the sense of understanding science's limitations, along with its possibilities, in terms of the broader cultural contexts that gave it meaning – the NSIS co-sponsored

[36] Michel Foucault's influential *The Order of Things: An Archaeology of the Human Sciences* (1966) might be the most obvious example of a burgeoning critical literature with science as its focus.

(in partnership with the AC Neish Memorial Trust) a series of AC Neish Memorial Lectures at Dalhousie University. Neish (1916-73), Dalhousie University's eminent biochemist and NRC Distinguished Research Scientist, had served as NSIS president in 1969-70, and had recently been inducted into both the Order of Canada and the Royal Society of London when he died in 1973. "Always deeply concerned about the future development of science and its impact on society," Neish inspired the lecture series intended "to foster understanding of science by providing the opportunity for members of the public to hear the views of distinguished scientists on the broader aspects of science and by giving them a chance to express their opinions during a question period." For, as one of the event's hosts pointed out, apparently with some surprise, "Despite the material well-being and leisure which science (and compound interest) have won for mankind, there still exists a deep-rooted and widespread irrational fear and distrust of science" (Simpson 1974; Manske, Masson, and McInnes 1977:106).

The four Neish lecturers offered interesting, thoughtful, deeply informed, and timely analyses in their efforts to open new paths of communication between science and society. The first, RHF Manske (1901-77) of the University of Waterloo, exhorted scientists and humanists alike to a mutual awareness of science and its social implications as a matter of "Science, Society, and Survival" in 1974 (Manske, Masson, and McInnes 1977). The second, AW Galston (1920-2008), Eaton Professor of Botany at Yale University, drew from his experience in North Vietnam to discuss the dangers of chemical defoliants in "Science and Social Concern: A Case Study from Plant Physiology" in 1977 (Blanchard 1978; Galston 1978). The third, FR Hayes, showcased the breadth of his knowledge in discussing the biologist EO Wilson's (1929-) controversial evolutionary theories of human culture in "The evolutionary basis for religious belief: Marx's takeover bid for Darwinian sociobiology" in 1978 (Wilson 1975; Cameron 1979; Hayes 1979). The fourth and final Neish lecturer, David Pimentel of Cornell University, tackled the timely issue of overpopulation in "Food, Energy, and the Environment" in 1980 (Pimentel 1981). In a wonderful capstone to the Institute's long list of speakers who resonated with the public – allowing it to peek behind the veil of science – during these years, the lecture by Stephen Jay Gould (1941-2002) of Harvard University, on "Pattern and Non-Pattern in the History of

Life"[37] celebrated the NSIS's 125th anniversary in 1987 with a record audience of 1100 (Bligh 1989).

B. Finding a Voice

Entering its most recent quarter century with a clear understanding of the need "to ensure that the community was well represented in the Institute," the NSIS welcomed the Science Teachers of Nova Scotia, Halifax's recently established Discovery Centre for science, local undergraduate science students, and Dalhousie University's Faculty of Engineering with observer status at NSIS Council meetings over the next few years. It also organized well-received panel discussions as "a further step in the examination of science in general e.g., strategies, research quality, funding and education." In a related outreach strategy, the Institute approached a public relations class at Mount St. Vincent University "to assist us in developing a heightened profile in the community"[38] that soon included involvement in school science fairs, science prizes, student mentorships, a science Hall of Fame, and forums on pressing popular issues such as climate change (Stewart 1993; Stewart 1994; Betts 2004; McCulloch 2005; O'Halloran 2008).

Conversely, the NSIS's Valley Chapter disappeared from its proceedings after 1988. Government cutbacks and university restructuring during the 1990s gave regional scientists a newly defensive common cause – and a concerned NSIS new opportunities to mediate in the other direction: to sponsor a meeting of engineers and scientists, to publish a directory of Nova Scotia's research facilities, and even to press government officials to support "basic [as distinct from applied and increasingly commercialized] science research." "Providing a collective voice for scientists in Nova Scotia," the Council declared in 1997, constituted one of its "main activities." Indeed, as president SH Heaps pointed out in 1998, "There is perhaps no other organization in Nova Scotia that is so well prepared to fill this role." Under these circumstances, he recognized, it was important to increase memberships "not primarily to collect more membership fees, but in order that we can claim to represent a larger cross-section of the concerned public" – from there, according to his successor, to take

[37] Gould had just published *Time's Arrow, Time's Cycle: Myth and Metaphor in the Discovery of Geological Time* (1987) and was working on *Wonderful Life: The Burgess Shale and the Nature of History* (1989).

[38] Students drew up a plan as one of their assignments; perhaps as a result, the Council hired a Publicity Officer in 2000 (Betts 2001).

on a role of active advocacy, "lobbying on behalf of the scientific community in Nova Scotia" and updating its mission statement with a commitment "to represent and promote science" (White[39] 1996; Gupta 1996; NSIS 1997; Heaps 2001; Niven 2001; NSIS 2008). To counter any implication that the days of JG MacGregor were over, however, President DHS Richardson deftly left no doubt, the following year, of the NSIS's "mission of presenting and promoting science, *especially research*" long recognized as "an endless undertaking" (author's italics; Richardson 2010; King 1940).

CONCLUSION

The NSIS really should be congratulated, in its 150th year, for having fulfilled its early members' hopes and dreams and, in particular, for having survived the brutal vagaries of the 20th century battle between time and place, with its soul intact. Its lengthy history is replete with dilemmas and dichotomies, with choices to be made not once, but many times over under changing circumstances: between city and countryside, where interested members have always resided; between increasing specialization in science and a public increasingly unable to comprehend its work without mediation; and between internal unity and disciplinary sectionalism, a choice that the Institute – unlike some other scientific societies – consistently decided *must* favour the former. Perhaps most importantly, the nature of the NSIS's commitment to science itself changed in tone, emphasis, and venue in response to shifting Ways of Knowing that repeatedly redefined the demands and expectations of both science and society over the course of the NSIS's existence. During its most recent 25 years it has found useful ways to serve both masters – and many of their rival constituencies – in the role of honest broker.

Some NSIS successes required little more than the "alert passivity" of a traveller with limited means hitchhiking to his next destination: "The thumb was perpetually in the traditional position but the head was shaken [at] several offers of a 'lift'" until more promising options appeared. In truth, such examples of good luck were few and far between, except perhaps when a potential NSIS speaker happened into the region for other reasons. Instead there was hard work behind repeated calls to "discover our essential self, lay it bare, and then foster

[39] Dr. Mary Ann White served as the NSIS's first woman president in 1994-95.

it delicately and with loving care. The fact that our Institute has an essential self," attested WJ Archibald in 1962:

> And that this self has in some measure been well-served, is indicated by observing that we have survived for one hundred years. No institution that fails to meet a need will last this long. It is not too easy to cut away cant and pomposity and see the true basis on which our permanence lies. Sometimes we claim that we are fostering this, promoting that, pursuing the other thing, and such meaningless phrases; however, I suspect that what really keeps us going is that we enjoy each other's company, we respect each other's ability, we are proud of each other's success, and that we value the chance to talk to each other about our work, to have it criticized and discussed in a friendly spirit. This is a perfectly sound basis for a successful society provided the topics discussed are important and relevant to a certain number of those present at each meeting (Archibald 1964).

Yet that could not be all there has been to it. As RJ Bean noted in 1942, "we would do well to think of our publication as the keystone of our whole organization":

> At times, the torch which we now carry has flickered dimly for various reasons, but never more seriously than when opinions that the journal should be discontinued, are cast about. We have been so accustomed over a period of years to the idea of huge enterprises, colossal figures, and concentrated power, that we often lose the sense of perspective which once lead [sic] us to consider that modest enterprise and limited activities were useful and worthwhile (Bean 1946).

This direct link between the *NSIS Proceedings* and the Institute's sense of its own well-being has always carried a powerful financial dimension. The decision to invest its funds in 1999 saw annual reports of the NSIS having attained more solid ground, but only while the recent policy of combining several years of *Proceedings* in fewer volumes, as they became more and more expensive to produce,

allowed the illusion of a slush fund to persist (Stewart 1996; Heaps 2001; Betts 2001).

Perhaps more importantly, the *Proceedings* have allowed the Institute, in the face of the presumption that dominated in science as industrial research during the early 20th century, once again to find its Nova Scotian moorings. As science itself came under unprecedented critical examination, the Institute chose not retreat but advance, hosting critical perspectives on social dimensions of modern science; and publishing, in the anniversary issue of the Atlantic Regional Laboratories, recollections of the difficult manoeuvrings by NSIS members behind the scenes to ensure the NRC's commitment to funding this important regional research centre. Pursuing this reaffirmation of its fundamental connection to place in a changing world, a born-again NSIS has more recently turned its *Proceedings*, along with the myriad digital resources it has made available, to recapture their role as the appropriate venue for publications of regional importance across the broadest spectrum of science, including original reviews of contemporary scientific issues from a critical regional perspective.

Without the Institute's unbroken series of published *Proceedings* – now digitized, and still a point of pride for their "worldwide" reach – there could be no history of this singular organization, because not enough of its unpublished records have survived, and not enough of what remains has been made accessible (where else but from minutes of meetings can we learn that "boiled [ie., heavily starched] shirts" were *de rigeur* attire for Major General McNaughton's NSIS audience in 1937 (NSIS Council Minutes 1937: 1 February)? Or that a large NSIS audience gathered late one night in 1922 to hear for the first time a musical radio programme transmitted from New York (NSIS Minutes 22 May 1922)?) The *Proceedings* not only harbor fascinating NSIS perspectives on scientific theories as they came and went over time; synopses of impromptu discussions that followed such presentations also offer invaluable hints of their reception, along with that of steam power and other technological wonders, including electric lighting. Maddening enticements continue to lurk in those 150 years of published pages, begging for historical and scientific follow-up. (Who knew that NSIS members anticipated television in 1926 as "just around the corner" (Ritchie 1926b); and that later generations dreamed of an NSIS television programme (Gupta 1996)?) What stands out overall, however, is that fascinating, fundamental, and,

at times, ruthless struggle between time and place in the Institute's history, and the gratifying fact that place continues to hold its own.

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THE FORMATION OF BRIGHTEST CLUSTER GALAXIES: THE CASE OF ABELL 407

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ABSTRACT

This article begins with a general introduction to galaxy formation and evolution and ends with a discussion of the long-term spectroscopic study: *The Role of Close Companions in the Formation of Brightest Cluster Galaxies and Intracluster Light*. To illustrate the power, goals and aims of this larger project, preliminary data for one of the galaxy clusters in our sample is presented, Abell 407, which appears to be caught in the act of forming its Brightest Cluster Galaxy (BCG).

INTRODUCTION

On a dark, clear night in Nova Scotia standing on your backyard porch looking up, you might spot one galaxy, our Milky Way. We live near the outer edge of one of the spiral arms of this disky-shaped collection of billions of stars. Could we could fly out of our galaxy, gazing down with a birds-eye-view, we would witness the Galaxy's spiral structure and recognize something similar to M31 (shown in the left side of the left panel of Fig 1).

The purpose of this article is to give a general review of our current understanding of the formation and evolution of galaxies and to present new data from a study currently in progress: *The Role of Close Companions in the Formation of Brightest Cluster Galaxies and Intracluster Light*. The introductory review goes as follows: an examination of galaxy types is found in Section – The Galaxy Zoo, a discussion of the large scale structure of the universe in Section – Looking Out, and we consider the benefit of looking at galaxies during different epochs of the universe's history in Section – Looking Back. The project description includes a brief discussion of the sample, the instrumentation used, the data analysis procedure in Methods, and the presentation of our images and spectra for Abell 407 can be found in

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Results. In the discussion we calculate very old stellar populations as well as short merging timescales for the central ellipticals. We conclude that the system will turn into a typically old large elliptical galaxy surrounded by an extended halo of intercluster light (ICL) in about 0.2 Gyrs. A full discussion of the results awaits the collection of the full sample, as argued in Future Work.

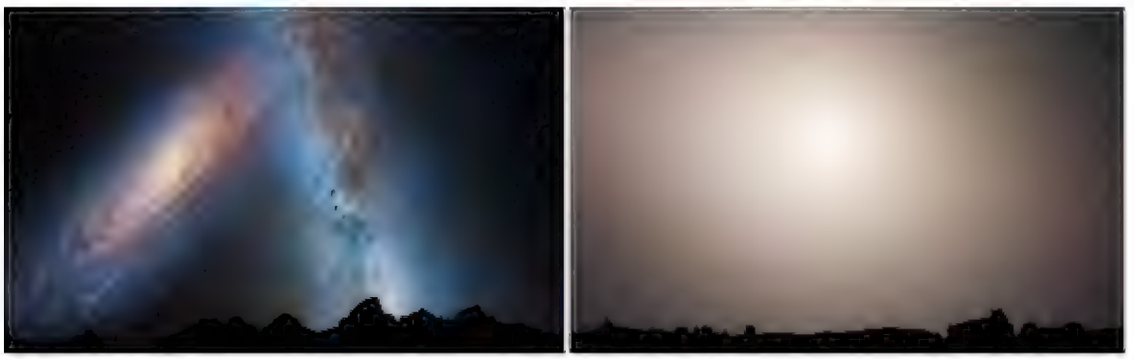

Fig 1 **On the left – The predicted view of the Andromeda Galaxy (left edge) with our Milky Way (central band) from Earth in 3.75Gyrs. On the right – Predicted view 7 Gyrs after the merger. The galaxy is dominated by old red stars and has become an elliptical galaxy. (Credit: NASA; ESA; Z. Levay and R. van der Marel, STScI; T. Hallas; and A. Mellinger.)**

The Galaxy Zoo: Spirals, Ellipticals and Encounters

Several of a galaxy's properties are used for developing a classification scheme. The best known of these might be Hubble's classification (Hubble 1922), the so-called 'tuning fork diagram' which sorts galaxies on the basis of their morphology, into spirals and ellipticals. Modern techniques also exploit a galaxy's size (mass or extent) as well as the analysis of the galaxy's overall colour. The latter is a proxy for discriminating between different stellar populations within a galaxy and has proved particularly important in trying to estimate the age and metal content of the system. This will become important in describing our own study, as these colours along with other diagnostics of the stellar populations can help to elucidate the evolutionary history of the galaxy.

The formation and evolution timescales can be constrained by looking at the galaxy's stellar populations, especially if single populations can be disaggregated from the whole of the galaxy. These populations are often parameterized by colour. There are many reasons that stars can be red: cooler blackbody temperatures emit more in red colours, and extinction by dust can redden starlight. In the case of tempera-

ture, stars turn red as they age since once they finish burning their core hydrogen, they become larger and cooler. On the other hand, the small, very low mass stars start out as red, and continue on that way for billions of years. In the case of dust, short wavelength light suffers more from extinction by dust along the line of sight, so that bluer stellar populations surrounded by dust are observed as having redder colours than only their starlight would otherwise indicate. The key lies in detecting bright *blue* stars. These are young since the most massive stars burn hottest and are necessarily short lived. This is the population that we see associated with the actively star forming regions typical of the arms in a spiral galaxy. These massive blue stars use up their hydrogen fuel very quickly, so that they are only seen for a (cosmic) blink of an eye, a few million years. They emit most of their light at such high energies that they glow at blue colours. Additionally, the high energy photons can ionize the surrounding gas, producing a key signature – an Hα emission line at 656.3nm. Hence, blue colours and Hα emission lines can be used as a clock, signalling the existence of current, or at least very recent star formation.

Many grand design spirals are seen to have a nearby neighbouring galaxy, a cosmic partner in crime. Simulations show how interactions between galaxies can trigger spiral structure (Purcell *et al.* 2011) as well as disturb the regular orbital patterns of the stars in each galaxy, forming tidal bridges and tails of stars that have been pulled off their host galaxy as the two interact via dynamical friction (Toomre and Toomre 1972). Over a few billion years the stellar orbits settle down around the combined gravitational potential of the two galaxies since they have merged into one elliptical. The product is much more red than the progenitors as the gas that existed in the two galaxies beforehand transforms in a huge burst of starformation triggered by shocks that are a result of the merger. Without any fresh gas, no new stars form and the galaxy reddens as the massive blue stars explode as supernovae and fade away. This will happen to us, as illustrated in Fig 1. The Milky Way and Andromeda are currently on a collision course, and it has been calculated that in about 5.86 billion years (van der Marel, *et al.* 2012) the two galaxies will merge into one large elliptical, Milkomeda (Fig 1, right).

But just how ubiquitous is this phenomenon? Were the largest galaxies today formed by the same process, just through more mergers over a longer time period (Dubinski *et al.* 1998)?

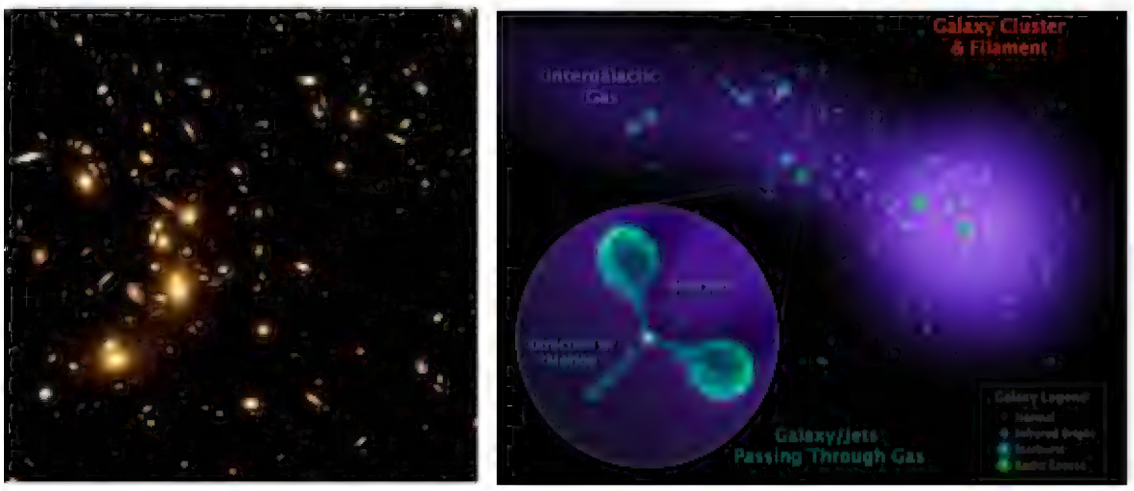

Fig 2 **On the left – A Hubble Space Telescope image of Abell 2744 of the Frontier Fields. Credit: NASA, ESA, J. Lotz and M. Mountain (STScI). On the right – The galaxy cluster Abell 1763 and its cluster feeding filament coming from the direction of Abell 1770. Image credit: NASA/JPL-Caltech and L. Edwards and D. Fadda.**

Looking Out – A Roadmap

The largest, brightest galaxies tend to live in particular environments. To visualize this, let's start by considering the environment of our own Milky Way. Creatively, our immediate neighbourhood is called the Local Group. This region is a collection of galaxies, including the Milky Way, Andromeda, and about 100 dwarf galaxies that have been identified as possible members (McConnachie 2012). However, most of the stellar mass in the universe is found in much larger systems. Fig 2 (left) shows the galaxies at the core of a rich cluster, wherein hundreds or thousands of galaxies are interacting gravitationally and occasionally colliding with one another as a part of their local supercluster. In turn, these superclusters are connected by filaments (Fig 2, right) where the galaxy concentration is much lower, and there are typically only 6×10^{-5} particles in a cubic centimeter (Edwards and Fadda 2010). 6×10^{-5} particles/cm^3! What is more, the regions between filaments and clusters are almost completely devoid of matter.

Our work will focus on the cores of local, rich galaxy clusters. These systems tend to have one or two extremely large galaxies at the gravitational potential of the cluster (see Fig 2, left and Fig 4). Old red stars dominate the stellar mass of the Brightest Cluster Galaxy (BCG). The galaxy morphology is elliptical, and there exists a noticeable lack of hydrogen gas clouds required to continue the generation of new stars. Thus, these galaxies have been called 'old red and dead'. However, blue stars have been found in their cores

(Bildfell *et al.* 2011) as has cold molecular gas (Edge *et al.* 2002) and Hα emission (ex. Edwards *et al.* 2007, McDonald *et al.* 2012). BCGs are often classified as cD type, a large elliptical galaxy with an extensive stellar halo that continues out for hundreds of thousands of light-years beyond the galaxy's core. While the distribution of the starlight in many BCGs follows smooth profiles, a large fraction also contain multiple nuclei (Laine *et al.* 2003) and close companions (Edwards and Patton 2012).

Looking Back – Our Time Machines

How did Brightest Cluster Galaxies get so big? That is a key question which must be adressed before it can be said that we understand the origin of BCGs. Since these galaxies sit near the base of the gravitational potential well of the entire cluster, they may have experienced a higher number of mergers, gaining more stars. Alternatively, these monsters may simply have been the first to start forming, having had more time to build their stellar component. This would imply an origin independent of their special position in the galaxy cluster. Intriguingly, when we observe the cosmic microwave background (Efstathiou *et al.* 1992) – before there were any stars at all – some regions of the universe were slightly more dense, and some slightly less so (see top panel of Fig 3).

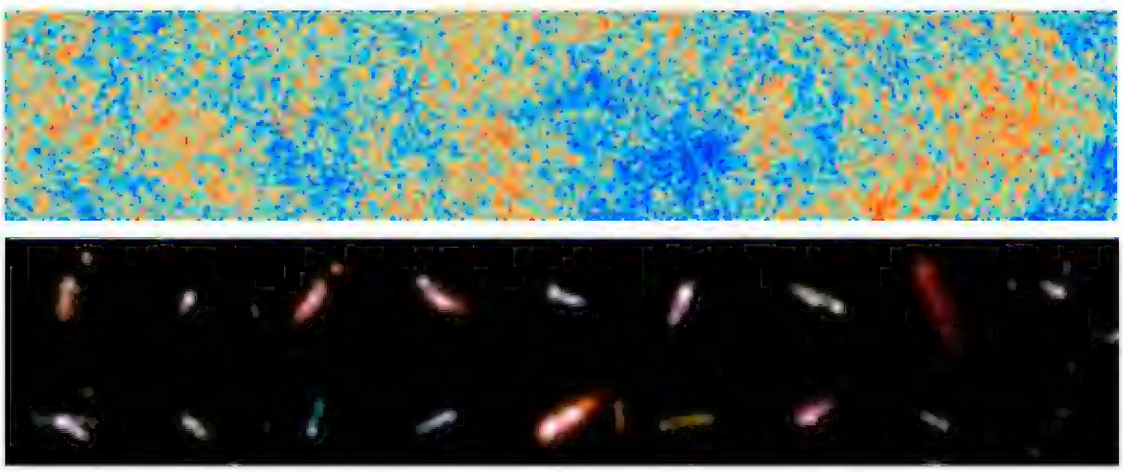

Fig 3 **Top – Anisotropies in the CMB from the Planck spacecraft. Credit: ESA and the Planck Collaboration, D. Ducros. Bottom – Young, very distant massive galaxies as seen in the Hubble Ultradeep Field. These galaxies have very irregular shapes suggesting ongoing mergers. Credit: NASA, A. Straughn, S. Cohen, R. Windhorst (Arizona State University) and the UDHF team (STSci).**

It is of course impossible to follow one cluster in time, as gravitational collapse and merging takes place over billions of years, but we can look at the properties of a sample of galaxies over several time

periods. Because it takes light time to travel, observing more distant systems can track those earlier on in their evolution. In fact, before about 8 billion years ago, clusters of galaxies held only 'trainwreck' galaxies, with no clear BCG (Krick, *et al.* 2009). The bottom panel of Fig 3 shows galaxies from Hubble Ultra Deep Field (NASA). Many of these galaxies are seen as they were after only about two billion years from the Big Bang (Straughn *et al.* 2005). Large elliptical galaxies with smooth cD envelopes have not been observed at this early epoch. They must evolve over time.

Fast forward 8 billion years, and Fig 4 (Edwards and Patton 2012) shows how dominant and elliptical the BCGs have become in local galaxy clusters. That study showed how BCGs have a higher number of close companions compared to the other bright red galaxies of a cluster. Liu *et al.* (2009) find a smaller number of close pairs for BCGs that are even more local. Such results are consistent with an enhanced merger history for BCGs in the past, as well as compared to other non-BCG ellipticals. But, to further our understanding, we need to look at more direct evidence as well. Searching for tidal tails and examining the stellar populations of the intracluster light will serve as direct evidence for the origin of the diffuse stars and its possible connection to galaxy encounters.

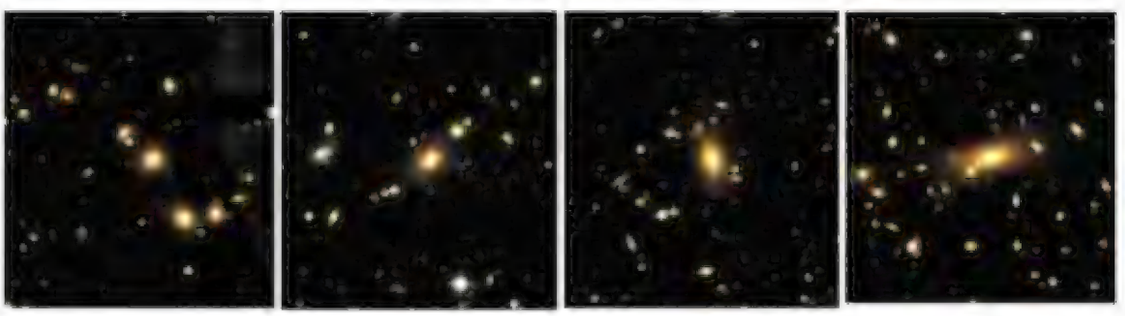

Fig 4 **Images of BCGs collected by Edwards and Patton (2012) from the CFHTLS cutout service (Credit: S. Gwyn). These clusters have redshifts between z=0.2-0.4. By this time in cosmic history, BCGs have formed and the dominant galaxies are very red and very large. Note especially in the last three panels how the cD galaxy is much brighter and larger than its nearby companions.**

METHODS

Our study will measure relative ages, metal content and star formation rates in a selection of BCGs, their nearby neighbours, and the surrounding intracluster light (ICL). We start with the NOAO Fundamental Plane survey's sample of 100 nearby rich clusters (Smith

et al. 2004). Choosing clusters that are observable from the WIYN telescope in Arizona, and at redshifts commensurate with angular source sizes fitting into the instrument field of view, 24 galaxies are chosen for observation. Over three observational campaigns, we have already been able to observe 12 of these systems using integral spectroscopy. Integral field units (IFU) are instruments that recover an entire spectrum for each small 'pixel' on the sky. Illustrated in Fig 5, IFUs allow us in one go, to get the light signatures from all three of the cluster core components. This section presents the instrument background and observations and the data reduction. The results and discussion of one of our clusters, Abell 407, follow.

Instrument Background and Observations

The data was collected using the SparsePak instrument (Bershady *et al.* 2004), which is mounted on the WIYN 3.5m telescope on Kitt Peak in Arizona. The spectrograph has 82 fibers arranged in a two-dimensional array, with a central core of 75 fibres and 7 sky fibres on the periphery (see Fig 5). Each fibre captures light from a circular field of 4.7" in diameter. The central core has on-sky dimensions of 72" x 71.3", while the sky fibres are another 25" away from the core. At the distance of Abell 407, this translates to 19.7 by 19.4 thousand lightyears, covering both the BCG and its close companions. A superposition of three pointings of the SparsePak grid fills the spaces between the fibres so that an integral image can be constructed at any wavelength between 400nm and 700nm.

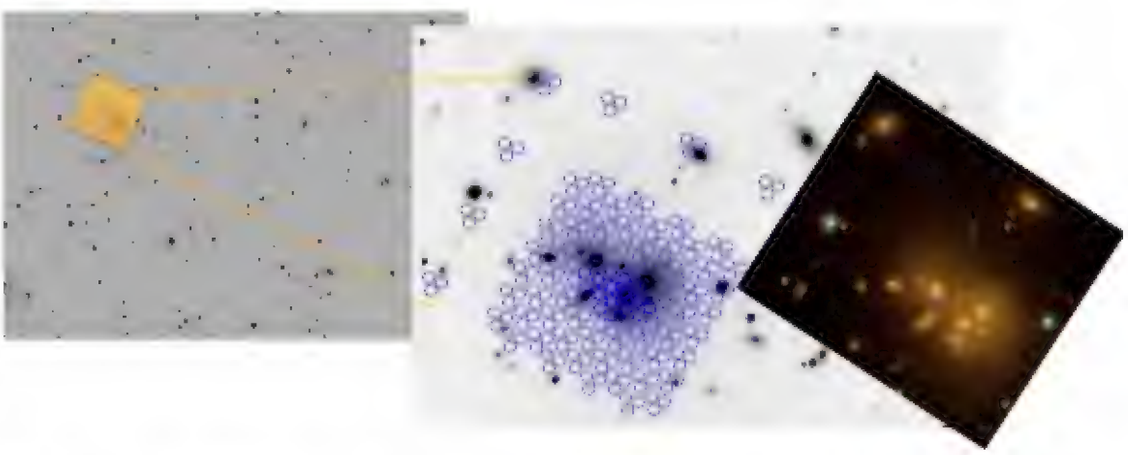

Fig 5 **Left – Wide field r'-band image from the Sloan Digital Sky Survey (SDSS), with overlay of Sparcepak instrument field of view in middle panel. Right – 3 colour SDSS image of the core of Abell 407. The dimensions of cut out are 72" x 71.3" or 19.7 by 19.4 thousand lightyears at the distance of Abell 407.**

Throughout the observing run, the instrument had a gain of 0.219 e-/adu and a readout noise of 3.4. For our spectrograph configuration, we used the grating 600@10.1 with a central wavelength of 570nm and the GG-420 filter to cut second order spectral lines.

Before observing the BCGs each night, sets of dome flats, arcs, biases and dark frames were taken. Flats are exposures taken on the dome to show defects of the CCD or other lighting problems; arcs are taken for wavelength calibration purposes; biases are zero second exposures that show the noise of the camera; and darks are taken with no light on the camera to reveal problems like hot pixels, or pixels with high leakage. Along with a standard star for flux calibration, all data for Abell 407 was taken in good weather conditions over the span of four nights between Nov 25 and 30, 2013. Data for 11 other clusters, from two other runs in 2012-2013 will be discussed elsewhere, along with the observations of additional clusters from Fall 2014.

Data Reduction

The data are pre-processed in the normal way using IRAF (Tody 1993). We subtracted detector bias and dark, and divided the normalized flat-field response of the CCD. We removed cosmic rays using the IRAF task *lacosic* (van Dokkum 2001) and subtracted the sky level using non-polluted Sparsepak sky fibres. We used the values from the NASA Extragalactic Database[1] to remove Galactic extinction and to correct for the published galaxy cluster redshift. Finally, we applied the flux calibration using the standard star.

RESULTS

Fig 5 shows an SDSS image of the core of the rich galaxy cluster, Abell 407. This is a very rare object as it has a great many large galaxies at the center of a poor cluster, it has even been referred to as the 'most nightmarish' of multiple nuclei central galaxies by Schneider and Gunn (1982). Some extended diffuse radio emission has been detected (Liuzzo *et al.* 2010), but the cluster is not a strong X-ray source. The continuum graph of Fig 6 displays the total intensity in the range of 5,500 to 6,000 angstroms for each fibre. This reconstructed image clearly shows light at the positions of the BCG (object N), and

[1] NASA Extragalactic Database is hosted by this site http://ned.ipac.caltech.edu/.

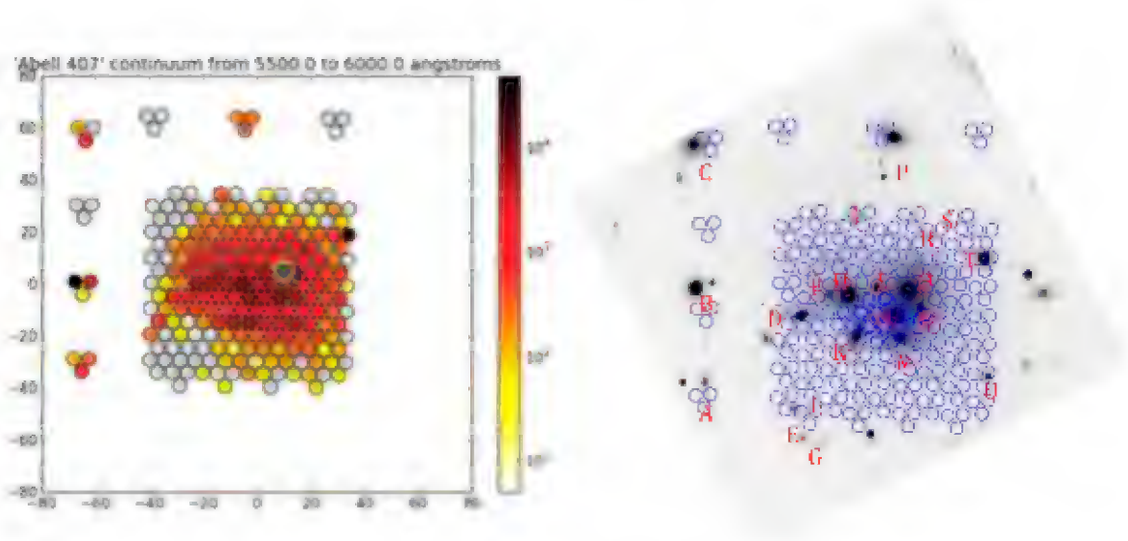

Fig 6 **Left – reconstructed image of the red end of the spectrum for all galaxies and starlight in the Sparsepak field of view. Credit: Hannah Alpert and Tara Abraham, undergraduate students at Yale University. Right – An SDSS r'-band image with three pointings of the Sparsepak fibres is overlaid on top. Sources A-U have been labeled in accordance to Table 1. Credit: Figure makes use of Jenny Power's Sparsepak visualization program (NOAO). The image scale uses false colours.**

other elliptical galaxies and foreground stars. The grey fibres represent outlier data with a signal-to-noise ratio too low to be meaningful.

Seven bright and 2 faint nuclei occupy the core of the cluster, within 10 kly of each other. An examination of Fig 6 reveals that all are within the projected area of the diffuse stellar halo – the false red and orange colours show the stellar envelope extends not quite to the outer edge of the IFU. In this section, we present the colours and magnitudes of the main galaxies as labeled in Fig 6 (right) as well as their spectra and velocities.

Colours and Magnitudes

Most of the highest luminosity objects are found to have very red colours, with the reddest colours being in the outer envelope of the brightest object (our O) and becoming slightly redder with increasing radius (Mackie 1992). By contrast, Schneider and Gunn (1982) found that the galaxies were slightly redder than the ICL.

Within the footprint of our WIYN data, we searched the Sloan Digital Sky Survey (SDSS) and found 21 photometric sources with r' magnitudes brighter than 21.9. Of these, Table 1 shows that seven are identified as stars by the SDSS star/galaxy separator, but only three (B, U and T) are clearly bright stars based on our spectra and

Table 1 **Photometric and kinematic properties of central nuclei. The first two columns give the position of the source on the sky, with the distance in " away from the central fibre of the home pointing. Photometry from the SDSS follows, with velocities and redshift differences as measured by our spectra. An * indicates an unreliable star/galaxy result or photometric data point.**

RA [Deg]	Dec [Deg]	ΔRA ["]	ΔDec ["]	g' mag	r' mag	(g'-r') a,k	S/G	Source	v km/s	dz
45.454732	35.833415	-34.77	-23.01	20.075	18.899	0.96	S*	U	-	-
45.455967	35.844637	-31.17	17.39	15.857	15.393	0.24	S	T	-	-
45.457521	35.848102	-26.64	29.87	22.512	21.714	0.58	G*	S	-	-
45.463170	35.839524	-10.19	-1.01	19.351	18.827	0.30	S*	Q	550	0.00184
45.464674	35.841178	-5.80	4.94	15.438	14.523	0.69	G	O	719	0.00240
45.465427	35.836556	-3.61	-11.70	19.019	18.637	0.16*	S*	M	514	0.00172
45.465933	35.838751	-2.14	-3.80	15.640	14.502	0.92	G	N	577	0.00193
45.467353	35.855764	2.00	57.45	17.464	16.447	0.80	G	P	-	-
45.470549	35.836642	11.31	-11.39	18.075	16.494	1.36	G	K	702	0.00234
45.471428	35.831307	13.87	-30.60	23.172	21.910	1.04	S*	G	-	-
45.471824	35.840490	15.03	2.46	15.647	14.735	0.69	G	H	496	0.00166
45.471852	35.848769	15.10	32.27	21.707	20.742	0.75	G	I	-	-
45.472998	35.830143	18.44	-34.79	22.485	21.875	0.39	S*	E	-	-
45.477227	35.838248	30.76	-5.61	18.169	17.202	0.75	G	D	413	0.00138
45.487927	35.840930	61.93	4.05	20.324	19.517	0.59	S*	B	-	-
45.488145	35.831325	62.57	-30.53	19.395	18.496	0.68	G	A	-	-
45.490939	35.854042	70.71	51.25	17.641	16.669	0.75	G	C	-	-

further inspection of the SDSS images. The table also shows that all galaxies are quite red, with (g'-r') colours greater than 0.35. Notable exceptions are sources T and Q, which are classified as stars by the SDSS. T falls squarely into one of the fibres, and the source spectrum is very clearly that of a foreground star. Source Q is less clear in that only part of its light falls into one of our fibres. Q's light is heavily polluted by that from O, N, M, and presumably the ICL. M, is clearly a galaxy by its spectrum and light profile. Its SDSS photometry is flagged as unreliable.

The brightest 3 galaxies (O, N, H) are very close in r'-mag, separated only by 0.2 mag, which is roughly the error. This means there is no clear optical BCG. K-band photometry in the near-IR can be a better measure of stellar mass, but only O and C and P have published photometry from the Two Micron All-Sky Survey (2MASS). From the Infrared Science Archive, the 2MASS K-band magnitudes are 10.409, 13.726 and 13.202, respectively. True cD galaxies are often the 1st ranked galaxy by a magnitude or more (ex. Abell 2029) – underscoring that Abell 407 has no dominant galaxy, therefore has BM Type II (Corwin 1974). When comparing the intensity at the red end of the spectrum to the blue end and (g'-r') colours of the ICL, H, N and O, we find that N has the reddest colours, with H, O and the ICL being indistinguishable in redness.

Spectra and velocities

By looking at the source velocity along the line of sight, we identified two foreground stars. None of the bright sources are identified as interloping galaxies.

Fig 7 shows the bright spectra we combined from all central sources within our field of view. The deep absorption lines of NaD, Mgb and Hβ are centered at nearly the same wavelength, consistent with all of the galaxies being physical members of the cluster. This is consistent with the data put forward by the NOAO Fundamental plane survey that these galaxies form a distinct subcluster. There are two notable exceptions: 1) Star T is clearly in the foreground and when the redshift applied is removed, the hydrogen absorption lines are clear. 2) Source R is too faint and too low S/N to resolve any absorption lines.

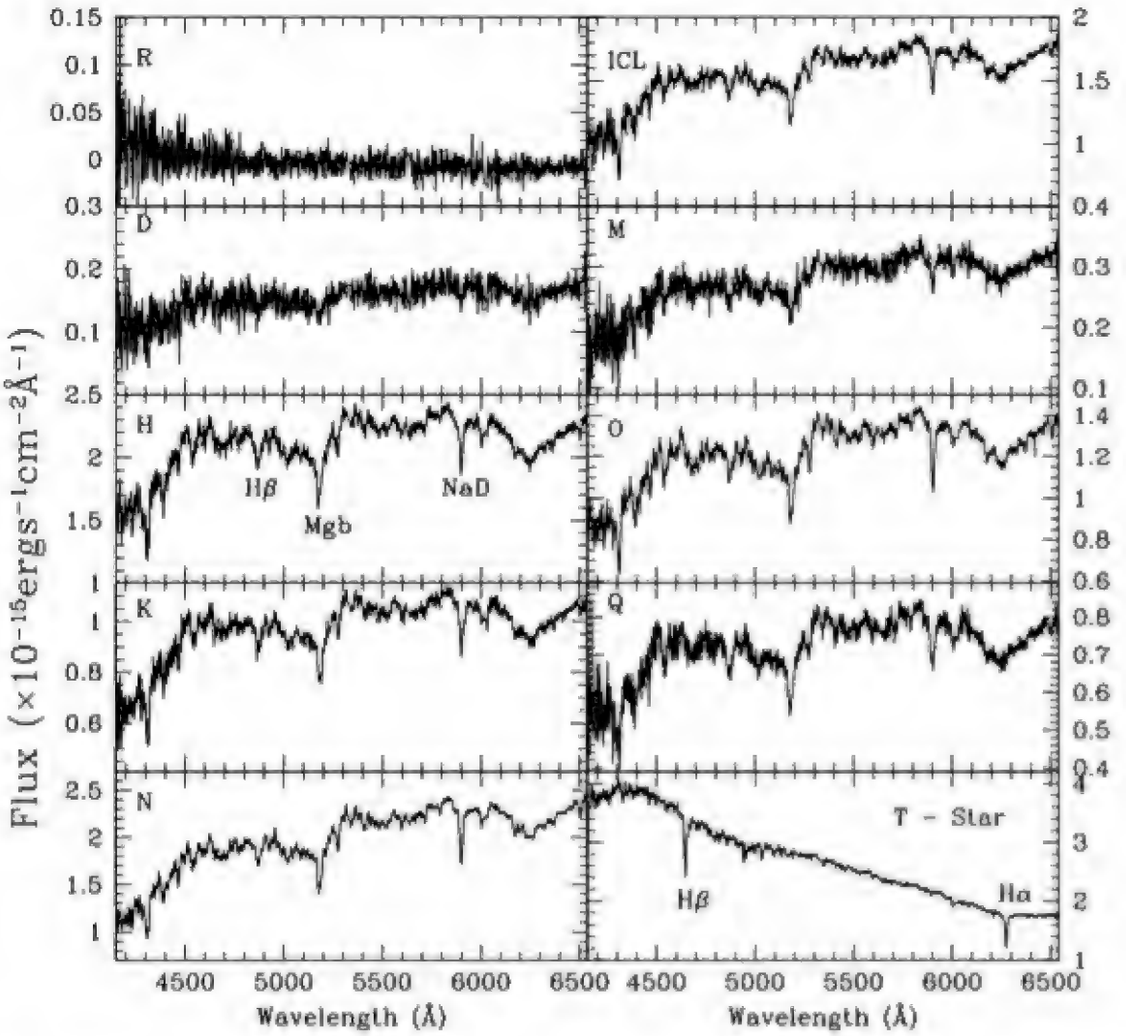

Fig 7 **Combined spectra of the brightest sources within the Sparsepak field of view. The sources are labeled as defined in Fig 6. Bright absorption lines are labeled in panel H. All spectra have been deredshifted to the published cluster redshift of 0.0462.**

DISCUSSION

Mackie (1992) conclude that the red envelopes they found in Abell 407 cluster galaxies could be from enhanced metallicity at the outer edges, from asymptotic giant branch stars (resulting from recent mergers) or from dust. It could also be that inner parts are bluer from current starformation, but we find no evidence for any strong optical emission lines, suggesting there is no significant ongoing star formation or active galactic nucleus (AGN) activity in the core. Our colours and spectra for all the central galaxies are consistent with a dominant old population.

To quantify this, we measure line strengths (Vazdekis 2011) on all of the bright sources of Table 1 to measure the Lick indices (depth of absorption lines, Worthey 1994). Most importantly, the results give

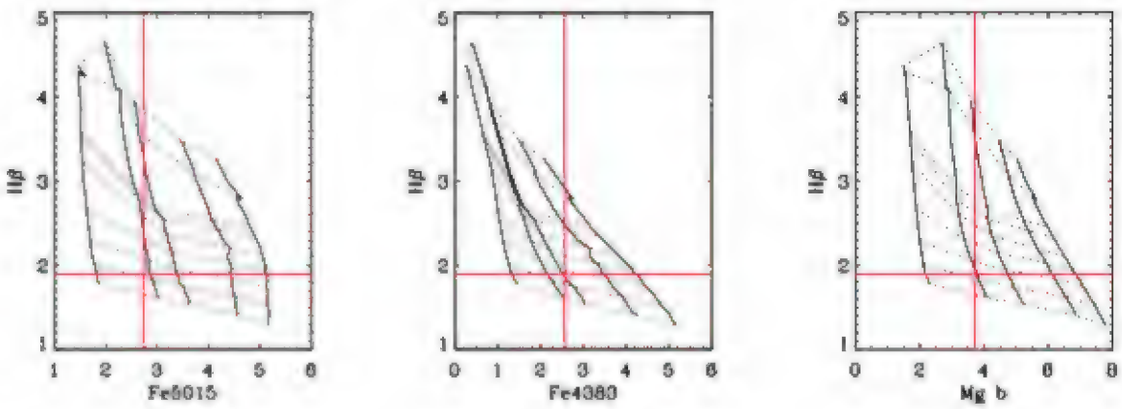

Fig 8 **Results from running the population synthesis code, EZ_Ages. Dotted lines are of constant age, increasing downward. The dotted line at the top represents an age of 1.2 Gyr, followed by 1.5, 2.5, 2.8, 3.5, 5.0, 7.0, 10.0 and 14.1 Gyrs. Solid lines are of constant metallicity, increasing to the left, starting with [Fe/H] = -1.3 and continuing on to -0.7, -0.4, 0.0 (solar), and +0.2. The red cross indicates the best-fit point for the ICL spectral indices. The stars are old and metal poor.**

the relative strength of Hβ and Mgb absorption. Although there is some degeneracy in these population indicators (Carter *et al.* 2009), in general for old populations, as the Hβ decreases, the age of the system increases, and as Mgb increases, the metallicity does as well.

Using the EZ_Ages population synthesis code (Greves and Schiavon 2008), we translate the indices into ages and metallicites based on the best-fit to stellar population models. The results are shown in Fig 8 for the integrated spectrum that belongs to the ICL. We compute an age of 9.04 Gyr and a metallicity of [Fe/H] of -0.71; these are old, metal poor stars. For the individual bright galaxies, the Hβ indices are even lower, implying even older stellar populations.

Schneider and Gunn (1982) performed a spectroscopic study on the galaxies of this cluster, collecting excellent spectra of the central nuclei, but not being able to achieve a high S/N spectrum of the ICL. These authors find that the three largest galaxies have velocity dispersions within 200km/s, which they related to a merging time of about a billion years. This would then be a very rare system, as we are catching the poor cluster, not in a steady state of inflow, but at a special time in history before all of the galaxies have converged into one cD galaxy. However, as these objects are in fact quite scarce in the local universe, this is possible. We compute the dynamical friction timescale of our measurements of the large galaxies. By using a velocity of 250 km/s and a companion mass of 6.63×10^{11} solar masses, and a distance of 25 kly, we estimate the system will have merged into one large cD galaxy in only 0.2 Gyr. We concur with Mackie

(1992) who claim that Abell 407 is in the process of building a larger cD galaxy. We detect ICL that echoes the major nuclei of the center in its morphology, and as the ICL does not exist much past the main nuclei, which is similar to the findings of Feldmeier *et al.* (2004), who find the little ICL that exists, closely follows the morphology of the largest galaxies of BM type II-III clusters.

CONCLUSION

We have shown that the central region of Abell 407 is home to 7 bright galaxies, where the 1st, 2nd and 3rd ranked members are all equal within the photometric errors. We confirm there is no clear cD galaxy, and that the system is BM type II. We have measured red colours for all three as well as absorption line strengths. The colours and absorption line strengths suggest a dominant old stellar population for all the bright galaxies, with an age of 9.044 Gyr with a low sub-solar metallicity for the ICL. We found no emission lines in the central, consistent with very old stellar populations in all nuclei, as well as in the ICL. Based on the paucity and irregular morphology of the ICL, we conclude that the brightest red galaxies are currently interacting, building a cD galaxy and as well as an extended ICL.

Using the redshifts of the individual galaxies compared to the cluster as a whole, we estimate the merger timescale by calculating the dynamical friction timescale, which turns out to be less than 0.2 Gyr. This is consistent with Abell 407 currently building a cD galaxy and ICL. Dubinski *et al.* (1998) predicts that morphologically relaxed clusters should have more ICL. In this unrelaxed cluster, we see no strong sign of ICL past 10 kly from the core. Additionally, the ICL morphology echoes the morphology of the large galaxies at the center of the cluster, and the colours are equally as red as the main galaxies.

Future Work

Once we have finished collecting our data, we will determine ages, metallicites, and star formation rates for a well determined sample of 15-20 nearby cluster cores. In addition to similar analysis on each of the clusters individually, we will be able to make a statement about the nature of local clusters in general and any links between the ICL, BCG and close companions. Does the ICL increase constantly with BM type or metallicity of the stellar populations? At what point in

the evolution do the blue cores of BCGs come into existence, and do they correlate with other cluster properties we have not discussed here, like AGN activity of X-ray brightness?

Final Remarks

We began this article with a general overview of galaxy formation and evolution. To end, let us consider the scale of Abell 407. It has a characteristic radius of roughly 20 kly and is about 708 million light years from the Sun. We suggest that from the time we saw the galaxies as they were, it would take ~0.2 Gyr for them to merge. Thus, 'today' this cluster would look quite different. It would not have 7 bright nuclei surrounded by a lumpy ICL, but rather would be dominated by one extremely large cD type galaxy, with old stars having been flung further out during the galaxy encounters, increasing the size of the ICL. Perhaps, during these huge mergers, small amounts of new stars would have been born, or would have triggered an AGN outburst, and the spectra would show Hβ in emission, rather than absorption. We would have to survive nearly another billion years to know about Abell 407's future for certain. But, amazingly, by looking at samples of galaxy clusters throughout several epochs, we will be able to quantify the plausibility of that scenario.

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the Michigan State/Notre Dame/JINA Participation Group, Johns Hopkins University, Lawrence Berkeley National Laboratory, Max Planck Institute for Astrophysics, Max Planck Institute for Extraterrestrial Physics, New Mexico State University, New York University, Ohio State University, Pennsylvania State University, University of Portsmouth, Princeton University, the Spanish Participation Group, University of Tokyo, University of Utah, Vanderbilt University, University of Virginia, University of Washington, and Yale University; the CFHTLS which is based on observations obtained with MegaPrime/MegaCam, a joint project of CFHT and CEA/IRFU, at the Canada-France-Hawaii Telescope (CFHT) which is operated by the National Research Council (NRC) of Canada, the Institut National des Science de l'Univers of the Centre National de la Recherche Scientifique (CNRS) of France, and the University of Hawaii. This work is based in part on data products produced at Terapix available at the Canadian Astronomy Data Centre as part of the Canada-France-Hawaii Telescope Legacy Survey, a collaborative project of NRC and CNRS. The IFU data for Abell 407 was taken at the WIYN Observatory which is a joint facility of the University of Wisconsin-Madison, Indiana University, Yale University, and the National Optical Astronomy Observatory.

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RESIDENT GREATER YELLOWLEGS ON THE EASTERN SHORE OF NOVA SCOTIA

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ABSTRACT

Resident Greater Yellowlegs (*Tringa melanoleuca*) were monitored over a five year period (2010-2014) at four sites within a selected 30 km by 30 km section on the Eastern Shore of Nova Scotia, Canada, to see if the sites are regular annual breeding territories. Three sites were occupied every year, while the fourth was only occupied in one year. There is evidence that adults arrive on site as bonded pairs, arriving as early as the third week of April, which is in advance of the peak in the seasonal continental migration. Brooding and chick rearing through May and early June enable fledging by the third week of June. Adults leave by about mid-July; juveniles have remained on site until late August. Encroachment by forestry and recreational activities appears to have been accommodated by nesting pairs.

INTRODUCTION

Greater Yellowlegs (*Tringa melanoleuca*) are present in Nova Scotia in all seasons of the year, particularly in the coastal zone, with peak numbers during the annual migrations (e.g., Tufts, 1986, 162). They are a species that is routinely monitored throughout the Canadian Atlantic provinces by many volunteers and birders who documented their sightings in *Nova Scotia Birds* (nsbirdsociety.ca) and in more formal surveys such as the Atlantic Canada Shorebird Survey organized by the Canadian Wildlife Service. How many pairs establish territories and nest regularly in the province has, however, not been well studied. McLaren (2012, 102) gives the status for Greater Yellowlegs in Nova Scotia as follows: 'This boreal-subarctic breeder nests very sparsely here in bogs and barrens, mostly in the n.e. mainland and on Cape Breton.' As stated in *The Birds of North America* by Elphick and Tibbits (1998, 18 & 10): 'The Greater and Lesser yellowlegs are among the most poorly known shorebirds in North America' and

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'currently, there are few quantitative data on diet, vocalizations, territory establishment or size, sexual behaviour, nest-site selection, breeding success, nestling growth and development, dispersal, demography, migration, and so on.'

The first Maritime *Atlas of Breeding Birds* (Erskine, 1992), conducted from 1986-1990, recorded breeding evidence largely from the Cape Breton Highlands, with just two sightings from the Eastern Shore of the mainland for an estimated total breeding population of 'under 100 pairs'. The recent second atlas (Stewart *et al*, In press) replicated, in general, the results for Cape Breton, but added significantly to sightings for the Eastern Shore region, including fledged young and distraction display. The greater number of sightings for mainland Nova Scotia during the second Atlas is probably not due to a population increase but rather to better road access and, as a result, more complete surveying of the Eastern Shore.

While participating in the *Second Atlas of Breeding Birds of the Maritime Provinces*, we observed, on a number of occasions, Greater Yellowlegs exhibiting behaviours that would suggest local breeding. Our atlas field work was in an area approximately 30 km by 30 km at the top end of the watersheds of the East River and West River Sheet Harbour, which are located in the Eastern Shore region of mainland Nova Scotia. Based on these initial spot sightings, we undertook non-invasive monitoring (between 2010 and 2014) of four sites to see if they were regularly occupied and therefore represent annual nesting sites. The data are used to identify habitat choice, to estimate the timing of the annual nesting cycle, and to monitor for pre- and post-fledging movements. For two of the years, monitoring of the annual coastal migration was undertaken for comparison purposes.

METHODS

Fig 1 shows the distribution of freshwater wetlands for the Eastern Shore as defined by the Nova Scotia Department of Natural Resources Wetlands GIS (NSDNR, 2013). The 30 km by 30 km 'square' outlined in the Fig delimits the area we surveyed over the atlasing period 2006-2010. Almost all possible habitat for Yellowlegs was surveyed, limited in a few locations by difficulty of access. The seven 'dots' mark the sites where spot evidence of local territory was observed, including strafing, aerial displays with territorial vocalizations, and

agitated/anxiety calls by adults. Four sites, labelled A, B, C, and D, were chosen for more detailed monitoring, with a more concentrated effort at a single site each year. Pat Lake is site A, Tent Lake is B, Belmore Flowage is C, and West Brook is D. The monitoring was intended to be weekly for the years 2010 to 2013, but was not always possible due to road conditions. For two of the sites, Pat Lake and Belmore Flowage, the regular use of a canoe made access easier and was significantly less disruptive. Monitoring of the chick rearing area was the priority, followed by stops at any known feeding areas - some of which are not on the same immediate watercourse used for chick rearing. In most cases the Yellowlegs themselves made us aware of their presence. If no initial response was seen or heard, two rounds of playback were used, based on the 'territorial' and '3-note' calls. Whenever possible, sightings were photographed to help confirm the identity of individuals. No nest hunting was done. An effort was made to minimize the impact of our presence.

Since the migrating Nova Scotia breeding population is a sub-component of the more general annual continental north-south migration, in 2011 and 2012 we explored the relative timing of spring-time arrivals and autumn departures along the coast and in the Eastern Shore nesting territories. The group of tidal mud flats found immediately east of Halifax is known to be a significant migratory stop-over for shore birds, including Yellowlegs, and these flats are a reasonable feeding/staging stop-over for territories inland along the Eastern Shore. Cole Harbour (a coastal tidal inlet located just east of Halifax) was a convenient choice. The number of Yellowlegs seen is thought to adequately capture the spring 'wave' of migrants, however the number seen on a given day at a given time can be highly variable.

RESULTS

Site habitats

The 30 km by 30 km 'square', located at the top end of the watersheds of the East River and West River Sheet Harbour, is a hilly hinterland varying in elevation between 125 m and 175 m; a forested (but heavily-logged) region with patches of wetlands. It is dominantly 'upland mixed' forest. As seen in Fig 1 the percentage of area classed as wetland, i.e., the 'density' of wetlands, varies, but there is

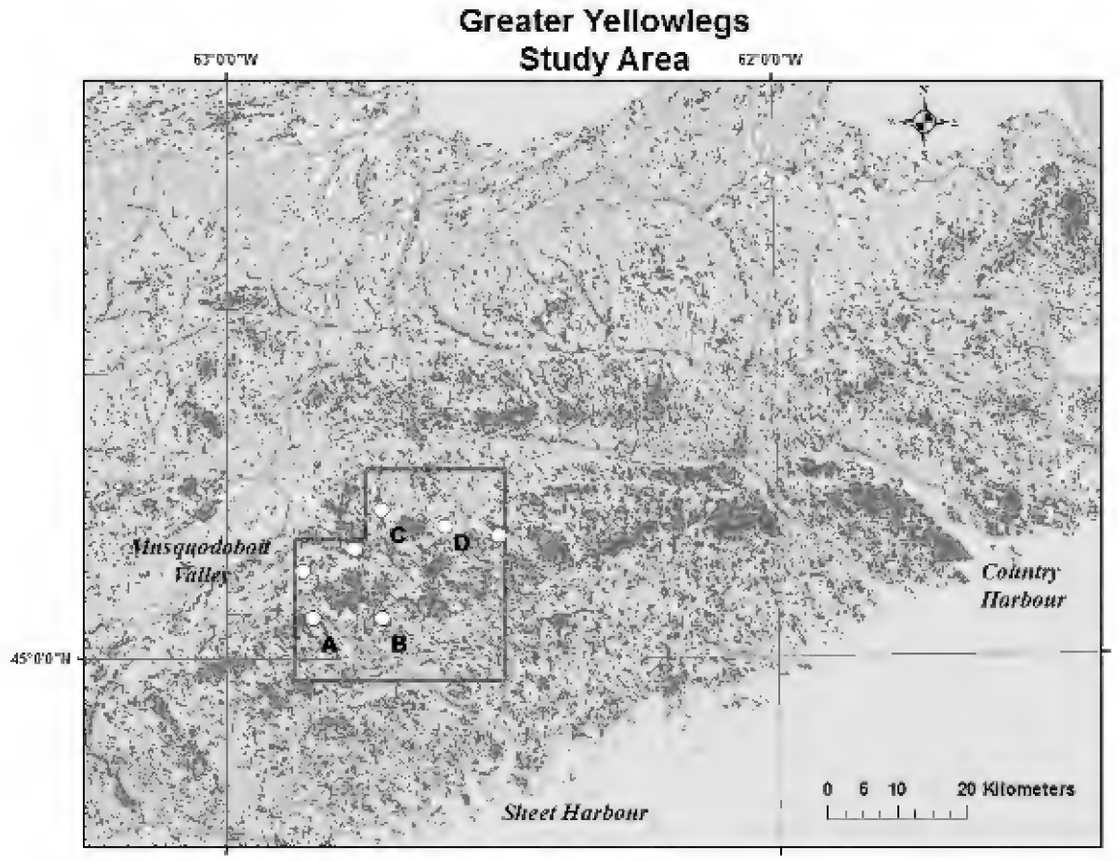

Fig 1 **Eastern Shore wetlands as depicted by the merging of all freshwater Cycle3 classifications in the Nova Scotia Department of Natural Resources Wetlands Data Base. This includes, 'open bogs ', 'treed bogs' and 'wetlands general'. Our study consists of a survey of all potential territory within the 30 km by 30 km 'box'. Seven potential sites found are shown as white dots. Four, listed as A-D, were chosen for annual monitoring. The wetland data were obtained under license from the 'Nova Scotia Department of Natural Resources'.**

a noticeably higher density associated with the headwater regions of the Eastern Shore rivers.

The four sites chosen for monitoring have a varied and different local mix of wetland types, but, apparently, each has a sufficient minimum habitat for nesting, for rearing of the precocial chicks through the critical first three weeks, and for dispersal of the juveniles. The habitat used for chick rearing, taken to be the most critical, is not the same wetland classification for all four sites, but all have a 'fen-like' characteristics as a dominant component; i.e. peatland (with snags or suitable trees and ground cover), a well-defined constant water course, and an associated upstream watershed limited to about one square kilometre.

For the Pat Lake site (Fig 2), the chick rearing area is the fen at the outlet of Pat Lake. Surrounding habitats are open and shrubby wetland, bogs, and a lake that includes organic mats. The Tent Lake

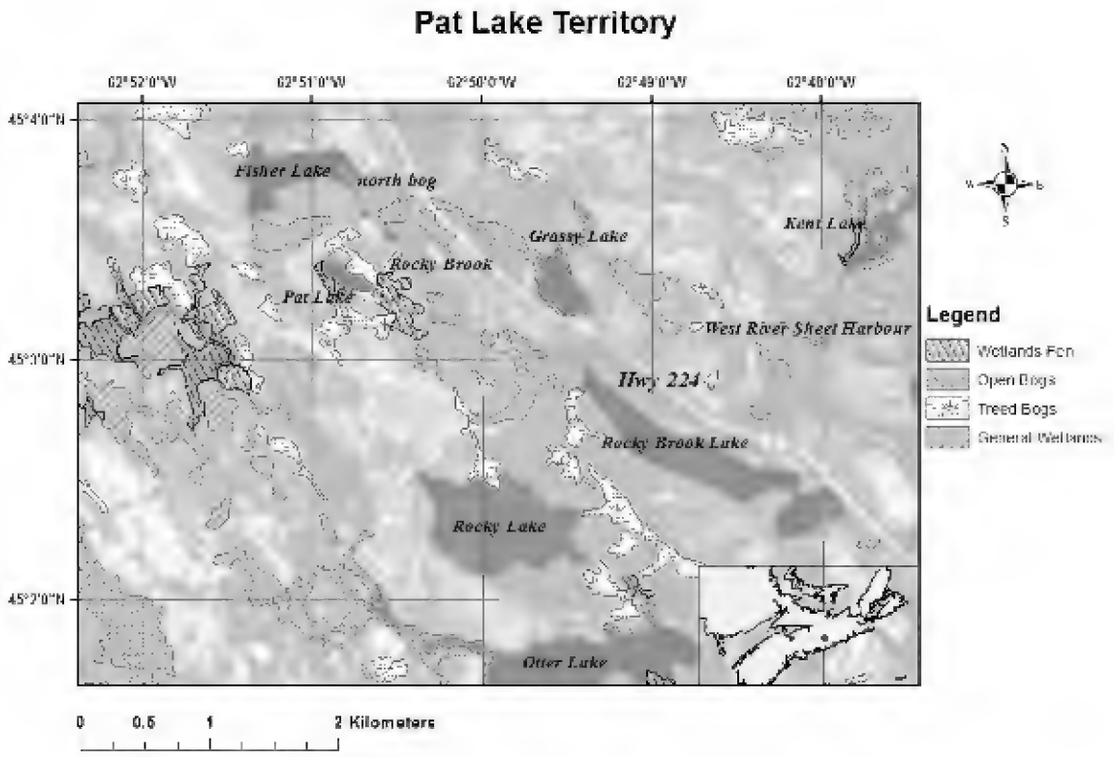

Fig 2 **The Pat Lake site detail. 'Open bogs',' treed bogs', and 'general wetlands' are Cycle3 data, the 'wetlands fen' are an overlay from Cycle2. The chick rearing site is the fen at the south end of Pat Lake. Family activities were observed to range from the un-named 'north bog' to the south end of Rocky Brook Lake. The orthophoto and GIS freshwater wetlands data were obtained under license from the 'Service Nova Scotia & Municipal Relations' and the 'Nova Scotia Department of Natural Resources'.**

site chick rearing area is integrated within a complex, merged mix of swamps and bogs that together combine to flow into Tent Lake. The Belmore Flowage rearing area is located near the mouth of a small stream that empties into a shallow alcove of the Flowage margin. The broad peatland margin of this two kilometre Flowage and the nearby Grassy Lakes with extensive organic mats, are feeding areas. The West Brook site is located within one branch of the brook. It is a small watershed bordering a roughly half-kilometre circular fen. Feeding areas are in the fen and along the brook.

Breeding cycle

A summary of key observations is given in Table 1. For three of the sites (Pat Lake, Tent Lake, and Belmore Flowage) Yellowlegs have been present every year (2010-2014). At the West Brook site they were present in only two years; that site was visited on three occasions in May in 2012 and 2013 with no indication of occupation. For all the sites, the earliest on-site arrival date observed was April 20. This date is likely near the earliest date to be expected for this region,

Table 1 Observations of the breeding cycle of Greater Yellowlegs

	Pat Lake	Tent Lake	Belmore Flowage	West Brook
Lat. /Long.	45.0534 N -62.8425 E	45.0519 N -62.7168 E	45.1927 N -62.7167 E	45.1690 N -62.6030 E
Years adults on site	2009-2014	2009-2014	2010-2014	2007 & 2011(i)
Earliest date seen on site	April 20 (2011)	April 20 (2012)	April 20 (2012)	May 4(i) (2011)
Chick/juvenile seen	July 8 2009 (one poss. two family of 3)	July 20 2011 (two feeding together)	June 6 2013 (one with adults)	
	July 8 2010 (three with adults)	Aug 1 2013 (one)	Aug 15 2013 (one)	
	July 9 2009 (one)	July 9 2014 (one with adult)		
	July 15 2009 (three with adults)			
	July 15 2010 (one)			
	July 19 2011 (one)			
	Aug 15 2013 (one)			
Last date family group seen	July 15 (2009)			

Note: (*i*) Site surveyed in 2012 and 2013. May 4 earliest date surveyed.

as lake and stream margins are often frozen through early April. No Yellowlegs were seen on frequent trips to Pat Lake in the first half of April for any year regardless of weather and none were present at Belmore Flowage by April 21, 2014.

The timing of the breeding cycle can be bracketed from the combined data. Juveniles were transiting between the rearing location and nearby (approx. 1 km) feeding areas by June 30 (2010) for Pat Lake and June 20 (2013) for Belmore Flowage. Actual dates for fledging could be earlier by up to one and a half weeks for Pat Lake and one week for Belmore Flowage given our sampling interval. However, from our estimated age of the young seen at Belmore Flowage on

June 6, 2013, the June 20 date is thought to be near first flight. Using the nominal times required for incubation and for hatched precocial chicks to develop fluttering flight as 23 days and 25 days respectively (Elphick and Tibbits, 1998), our data suggest typical dates as: earliest arrival within the last weeks of April, incubation started by the end of first week of May, hatching near end of May (23 days), fledging by third week of June (25 days), and moving amongst prime feeding areas through July/August. In 2011, at Belmore Flowage, territorial competition between males was underway on May 3, in line with the above.

Also, as seen in Table 1, are the dates when young were seen at the four sites. Although observed, we have not tabled occasions when we thought females were vocally instructing hidden young. Young with adults were seen up until mid-July. Young were present at two sites until mid-August in 2013. The Pat Lake location, frequently used by juveniles, appeared to be abandoned much earlier in 2010. That year over 11 cm of rain occurred between July 12 and 15; Pat Lake levels rose by about 20 cm and local flooding was evident for some streams. No evidence of individuals at any of the usual feeding sites was found in the days following. Thus weather, including a heavy rain event, may influence the time of final departure.

Feeding activities

Because of our limited spatial and temporal coverage, these data do not reveal every feeding location or the outer boundaries of a defended territory. However, the Belmore Flowage, which is about two kilometres long with diverse shoreline habitat and with a chick rearing site at midway, appears to be the extent of occupied territory and feeding areas from first arrival in April to fledged young. Territorial competition (May 3, 2011) ended when the interlopers left the Flowage. On all occasions two adults were seen feeding during the pre-brooding phase and at least one during brooding. During brooding the male was seen and occasionally the female would be seen or heard. After hatching the female and 'young' remained within about a half kilometre of their small embayment. In this phase the male was present, often vocal, with occasional strafing. After fledging, the family used both the flowage and the Grassy Lakes, two kilometres upstream, as feeding areas.

Pat Lake and Tent Lake had a similar pattern. At Pat Lake, pre-hatching, the male maintained a mostly silent vigil near the

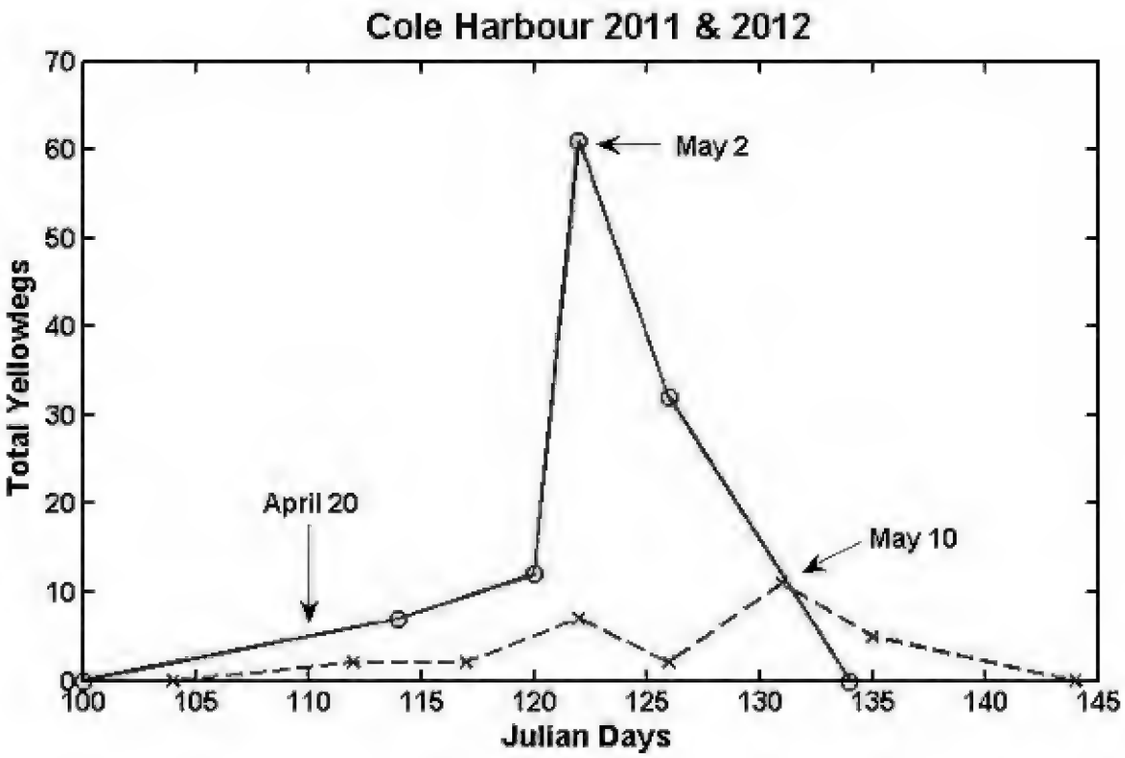

Fig 3 **Dates of arrival of Yellowlegs 'on territory' on the Eastern Shore, April 20, relative to the occurrence of migrating Yellowlegs as seen passing through at the Cole Harbour tidal flats in 2011 'o' and 2012 'x'. One adult was 'on territory' on April 20 in 2011, which is Julian date 110, and three in 2012, Julian date 111. In both years the Eastern Shore 'on territory' arrivals are at the leading edge of the annual spring migration.**

rearing fen. After hatching the female remained within the fen area. After fledging, family activity, with 'family chatter', was observed from the 'north bog' to the south end of Rocky Brook Lake, Fig 2. For Tent Lake all sightings were within the fen/bog/swamp complex, a domain of about one and a half kilometres diameter.

Migration

Eastern Shore Greater Yellowlegs are early spring arrivals. When we compared arrival dates on territory to the passing coastal migration, the Eastern Shore population is seen to be arriving on the leading edge. The comparison, undertaken in 2011 and 2012, is shown in Fig 3. The year 2011 was locally considered as a 'late spring' associated with foggy/rainy weather, while 2012 was an 'early spring' with open water on lakes by late March. In both years, Yellowlegs were seen on territory by April 20. This date coincides with the earliest arrivals seen on the coast (Cole Harbour).

In addition to being 'early' arrivals, there is evidence that Yellowlegs are migrating and arriving on site as mated pairs: 1) on April 20,

2012, an early arrival pair of Yellowlegs at Tent Lake gave territorial calls and display, 2) on each of two occasions, well in advance of the arrival of the main migration, a pair of Yellowlegs in migration were feeding together at Cole Harbour (April 21, and 26, 2012), 3) at Cole Harbour on May 1, 2012, a bonded pair used the joint three- or four-second volley of the 3 note calls followed by the male giving a roughly four-second round of territorial call, calls identical to those used by a pair arriving on April 20 at Tent Lake, and 4) on May 3, 2011, two pairs of Yellowlegs were in serious competition for territory at Belmore Flowage.

Dispersal of the families from the nesting sites in mid-July is characterized by fewer adults and single juveniles scattered at various territorial feeding sites. Latest dates for inland family groups is about mid-July, and for juveniles, mid-August. This coincides with the appearance of more individuals, adults then young, at the 'local' coastal tidal flats.

DISCUSSION

Our observations that Yellowlegs are arriving on site as bonded pairs is similar to the behaviour of a closely related species, the Greenshank (*Tringa nebularia*). The Greenshank has migration/territory in northern Scotland similar to the terrain of Nova Scotia. In Scotland the prominent local, migration feeding areas are in 'particular bays and inlets of a firth or a larger loch' at a convenient distance from the nesting/rearing sites (Nethersole-Thompson and Nethersole-Thompson, 1979, 101ff.). It is thought that these areas also serve as 'mating territories' where 'mating' occurs or 'pairs re-mate'. A similar pattern would fit our Nova Scotia observations. The coastal mud flats (not restricted to the group immediately east of Halifax) would be suitable, prominent, and identifiable mating territories. These are the only obvious common gathering points for the Eastern Shore. Located along the natural migration route north, they would be familiar territory as they are a major initial autumn feeding stop-over.

The regular annual occupation of the nesting/rearing sites suggests that this region of the Eastern Shore has the necessary mix of suitable habitat. As shown in Fig 2, the wetlands near Pat Lake are a mix of habitat classifications and are not particularly extensive; some are patches no more than a few hectares, or margins less than 100m wide.

The other three sites monitored are equally compact and diverse. The Wetland Inventory on the Nova Scotia Department of Natural Resources website (NSDNR, 2013) shows a similar mix of habitat classification and density throughout the higher wetland 'densities' as shown in Fig 1. Thus potential territories could extend along the entire inland region of the Eastern Shore from east of the Musquodoboit Valley, including the watershed of the West River St. Mary's, down to the coast at Country Harbour, a length of approximately 120 km. It is within this region where most of the mainland Yellowlegs were recorded in the Second Atlas. The distance between the nesting sites in our study varies between 7 and 15 kilometres, or roughly 10 km. This breeding density number is similar to the lower numbers seen for northern breeding populations: the lowest population density seen in the Ontario atlas (Cadman *et al*, 1987) is about one per 10 km square. For this nesting density the Eastern Shore has sufficient wetland for at least 30 pairs.

The Pat Lake and Tent Lake sites provide examples of accommodation to increased human encroachment. The first atlas (Erskine, 1992) recorded a Yellowlegs confirmation near Pat Lake. Since the first atlas clear-cut logging continues, cottage country has expanded, and fishermen are more numerous. Family cottages are now at the edge of the Rocky Brook Lake feeding area. Clear cutting of the forest on all sides of the nesting, rearing and feeding areas has taken place. Recently, tree harvesters worked through June and July, 2011, to within 10m along the edge of the rearing/nesting site for what was a successful breeding year. At the Tent Lake site a major haul road cuts through the breeding wetland complex, yet adults and young still feed roadside. The same forestry practices apply to the other sites, and yet the Yellowlegs persist.

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breeding behaviour and ecology of the greater yellowlegs and thus achieve a better understanding of two wonderful birds.'(Nethersole-Thompson and Nethersole-Thompson, 1979, 214).

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ELEMENTAL FINGERPRINTS OF OTOLITHS FROM SMOLT OF ATLANTIC SALMON, *Salmo salar* Linnaeus, 1758, FROM THREE MARITIME WATERSHEDS: NATURAL TAG FOR STOCK DISCRIMINATION

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ABSTRACT

The utility of otolith elemental fingerprints for discriminating sub-regional stocks of Atlantic salmon was examined. Otoliths were removed from Atlantic salmon smolts collected from three individual river watersheds in the Canadian Maritimes during spring and analyzed for 27 elements using inductively coupled plasma mass spectrometry (ICP-MS) and inductively coupled plasma emission spectrometry (ICP-ES). Calcium and minor and trace elements were precisely measured in whole otoliths at concentrations well above detection limits. Six elements (Ba, Pb, Li, Mn, Rb, and Tl) were significantly different among watersheds. Linear discriminate function analysis based on otolith elemental concentrations of Li, Mn, Rb, and Tl correctly classified smolts to their river of origin with an average accuracy of 73%. At a slightly greater spatial scale of large watersheds, correct mean classification rate was 92% based on a fingerprint of four elements (Ba, Li, Mn, and Rb). Results indicate that elemental fingerprints of otoliths can be used to discriminate among river management stocks which may be important in the future since dried or frozen stored otoliths retain their signature indefinitely and otoliths are often available from previous studies. Otolith elemental fingerprints would be effective as a natural tag of a river system or biogeoclimatic zone of origin when applied to the study and management of Atlantic salmon in the North Atlantic Ocean.

INTRODUCTION

Effective fisheries management demands the prediction of temporal trends in population abundance and productivity so that sustainable biological limits on harvesting can be set (Hilborn and Walters 1992).

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Anadromous salmon species form reproductively isolated populations, which are managed as distinct units or stocks, yet they are distributed over a vast area (i.e., oceans) outside of managementareas (i.e., rivers) for a large portion of their life. Recently, a more holistic approach to salmon management has been suggested, one that considers the ocean conditions which primarily determine spawning recruitment (Bisbal and McConnaha 1998). An essential component of this management strategy is a thorough understanding of the spatial and temporal marine distribution of individual river management stocks. Data collection, however, required to describe life histories of specific river stocks is complicated by the need to discriminate each stock from the mixed assemblage of fish being sampled in the ocean or in some fisheries.

Each year, juvenile anadromous Atlantic salmon, *Salmo salar* Linneaus, 1758, of appropriate size, undergo smoltification and migrate downriver to the sea (McCormick *et al.*1998). Post-smolts emigrating from different watersheds move through common migration corridors (Shelton *et al.* 1997; Lacroix *et al.* 2005; Byron *et al.* 2014) and then distribute over broad oceanic regions (Holm et al 2000; Soto *et al.* in review). During feeding migrations in the North Atlantic Sub-polar Gyre, populations become aggregated and mixed together (Dadswell *et al.* 2010). After 1–5 years of marine residency, mixing of both regional stock groupings (Reddin 1985; Jacobsen *et al.* 2001) and the two continental stock complexes (Møller Jensen 1980a, 1980b) occurs as North American and European origin Atlantic salmon undertake trans-Atlantic migrations between ocean feeding grounds and freshwater spawning rivers.

The anadromous life cycle and long distant migratory behavior of Atlantic salmon presents many opportunities for their interception by fisheries at sea and coastal and estuarine salmon fisheries indiscriminately harvest individuals from different river stocks that can vary greatly in productivity and which can lead to a significant decline in recruitment or even collapse of some management units (Crozier *et al.* 2004). While Canadian and American commercial Atlantic salmon fisheries have been terminated (Chase 2003), other commercial and subsistence fisheries continue to operate in the exclusive economic zones: France (Saint Pierre and Miquelon), Denmark (Greenland), Norway, Ireland and the United Kingdom (UK; ICES 2009). Also, there are recreational angling fisheries in many rivers of Atlantic Canada, Iceland, Ireland, the UK, the Nordic countries, and Russia. Determining the geographic origin of migrating individuals to

estimate the degree of mixed stock composition of trans-boundary and straddling stock fisheries remains an important management issue throughout the North Atlantic.

During the past decade, advances in analytical techniques used to identify and quantify the chemical composition of biological samples have encouraged the application of elemental and isotopic marks in the tissues of fishes as an alternative method to test stock discrimination (Campana 2005). Both calcified and non-calcified fish tissues can incorporate elements and isotopes characteristic of physiological, dietary, or ecological events that individual fish have experienced. These events impart a signature of past exposure in the tissue structure which allows for relative chemical information to be collected

(Elsdon and Gillanders 2003a). Indeed, elemental and isotopic signatures in a variety of Atlantic salmon tissues have been used to retrospectively detect migrations and infer distributions (Tucker *et al.* 1999; Spares *et al.* 2007), and distinguish populations (Flem *et al.* 2005; Veinott and Porter 2005; Martin *et al.* 2013). Selecting the appropriate tissue to analyze is essential since chemical composition can differ among tissue types (Gillanders 2001). Tissue structures that are not susceptible to metabolic reworking are required to link chemical signatures to discreet time periods in the environmental record.

Sagittal otoliths, usually the largest of the three otolith pairs, are composed predominately of calcium carbonate crystallized in the form of polycrystalline aragonite (Campana 1999). As fish grow, otolith formation occurs by the sequential layering of calcium carbonate and protein precipitated from the endolymphatic fluid surrounding the otolith to form a crystalline-proteinaceous matrix (Campana and Nielsen 1985). Calcium carbonate is the dominate component (>90%), followed by protein (<8%), with the remainder being non-organic impurities such as minor (> ppm) and trace (< ppm) elements and their isotopes (1–2%). Campana (1999) reported that a total of 31 elements had been detected in otoliths with the majority occurring at low concentrations (<10 ppm) and presumably more are awaiting detection as new analytical techniques that improve properties of accuracy, precision, and sensitivity of analysis are developed. Still, detection of either a given element or isotope in the otolith is not simply a function of instrumentation because the presence and concentration are influenced by numerous environmental factors (Elsdon and Gillanders 2004) and the physiology of the individual (Kalish 1989).

To reconstruct environmental histories or discriminate among mixed groups of fish which have inhabited different past environments, elements under strong physiological control (e.g., C, O, H, N, S, Cl, K, and P) may be of minimal use since they have been found to vary little among populations (Campana 1999). Elements that have been shown to reflect environmental availability are predominately the alkaline earth metals (e.g., Ca, Sr, Ba; Farrell and Campana 1996; Bath *et al.* 2000; Elsdon and Gillanders 2002, 2003b) and their isotopes (e.g., $^{87}Sr/^{86}Sr$; Kennedy *et al.* 2002), some of the alkaline metals (e.g., Li; Milton and Chenery 2001), and, to a lesser extent, the transition metals (e.g., Mn; Dorval *et al.* 2005). For freshwater fish, the primary source of elemental uptake occurs via water passing over the gills, which is influenced by relative Ca concentration in the water (Campana 1999). For some elements assimilated into the otolith matrix such as Sr and Ba, elemental concentration relative to Ca may be the most indicative measure of environmental availability for fish residing in freshwater as opposed to the absolute concentration of the element (Campana 1999). In studies focusing on fish population dynamics in both lotic and lentic freshwater systems, referencing elemental concentrations to Ca has proven extremely successful for identifying geographic origins (Wells *et al.* 2003a; Brazner *et al.* 2004b; Martin *et al.* 2013).

The underlying premise of this approach is based on two key properties of the otolith: the growth of the otolith is continuous from before the time of hatch to the time of death and material deposited onto the growing surface of the otolith is unlikely to be reworked or resorbed due to its metabolically inert and acellular nature (Campana and Neilson 1985), and (2) the calcium carbonate, trace elements and isotopes that comprise greater than 90% of the otolith in the fish are mainly derived from the ambient water (Campana 1999). This implies that the chemical and physical composition of the environment is reflected in the otoliths of individual fish providing a permanent record of exposure structured by age. Therefore, concentrations of elements and isotopes incorporated into increments of the otolith corresponding to the juvenile life stage provide a natural tag or fingerprint (Campana *et al.* 1994) specific to a particular natal water mass which can be used to discriminate among stocks of fish from different origins.

In our study, the utility of otolith chemistry as a method for identifying Atlantic salmon to river of origin was assessed. Specifically, the objectives were to (1) quantify the variation in trace element chemistry in the otoliths of Atlantic salmon smolts from three

different watersheds in the Canadian Maritimes and (2) test the ability of the differences in otolith elemental concentrations among river stocks to accurately classify individual Atlantic salmon smolts to river of origin. Smolts were sampled for two reasons: (1) to ensure that the characterization of otolith elemental fingerprints for discrete reference groups were accurate by removing the possibility of stock mixing prior to sample collection since smolt remain in, or at least near, natal rivers until migration into fully marine waters (Cunjak *et al.* 1989); and (2) to allow for analysis of the entire juvenile portion of the otolith corresponding to the period of time before hatch until the period of time just prior to marine residency thus deriving elemental fingerprints characteristic of the entire freshwater life history stage.

The rationale to base elemental fingerprints on the entire freshwater phase was to provide an approach to sampling the otoliths of ocean migrating Atlantic salmon for determination of stock identity with high replication capabilities and to use a part of the salmon that preserves the stock identity and can be easily stored without damage. In most commercial and angling fisheries the salmon are processed quickly leaving only the head containing the otoliths available for scientific study (Tucker *et al.* 1999; Spares *et al.* 2007). Additionally, fisheries are often remote (Labrador, Greenland, etc.) and freezing, which destroys DNA for stock analysis, is used to maintain the samples. Bulk examination of otolith chemical composition should provide a level of resolution adequate for accurately classifying individual salmon to river of origin while at the same time offering an economic and time-efficient means of analysis (Campana *et al.* 1995b).

STOCK WATERSHED DESCRIPTIONS

The Department of Fisheries and Oceans Canada (DFO) utilizes the index river monitoring program in the Canadian Maritime provinces to evaluate the status of Atlantic salmon stocks in nearby or similar rivers located in the same biogeoclimatic zone (Chadwick 1995; DFO 2003).

The Miramichi River, New Brunswick, Canada is part of DFO's Gulf Region and is the largest river system in the New Brunswick Southeast Gulf biogeoclimatic zone (DFO 2003, 2006; Fig 1). The river is approximately 250 km in length and consists of two main branches, the Northwest and the Southwest, which drain watersheds of 3900 km^2 and 7700 km^2, respectively (DFO 2001a). Both the Northwest

Miramichi River and the Southwest Miramichi River originate in the Ordovician, Silurian, and Devonian granitic and volcanic rocks of the north central Miramichi highlands and flow predominately eastward where they join below the head of tide in the Maritime Plain which is underlain with sandstones, conglomerates, and siltstones from the Pennsylvanian period or earlier (Chiasson 1995).

The Margaree River, Nova Scotia, Canada is also part of DFO's Gulf Region and is the principal river in the Nova Scotia Northumberland Strait and western Cape Breton Island biogeoclimatic zone (DFO 2003, 2006; Fig 1). The Margaree River is comprised of two main branches that drain a combined area of 1165 km^2 and have a combined length of 120 km. The Southwest branch originates at Lake Ainslie and flows through Carboniferous sedimentary rock (Barr and Reaside 1989) in a northerly direction to join the Northeast branch flowing south from its headwaters, which drain the highlands of Cape Breton. The Northeast branch intersects crystalline and metamorphic rock before it joins with the Southeast branch (MacNabb *et al.* 1976).

METHODS

All 97 Atlantic salmon smolts sampled were collected during the spring smolt migration period (Table 1). Fish were captured with trap-nets in the Northwest Miramichi River at Cassilis, New Brunswick and in the Southwest Miramichi River at Millerton, New Brunswick and with a rotary screw trap near the head of the tide in the constricted main stem of the Margaree River (Clément *et al.* 2007; Fig 1). They were then placed together in plastic bags according to river and date of collection and frozen until otoliths were removed.

Table 1 Summary information and descriptive statistics for Atlantic salmon smolts sampled from three watersheds in the Canadian Maritimes. Mean ± SE age, fork length, and otolith mass are given.

Watershed	Biogeoclimatic zone	Number of fish	Age (yr)	Fork length (cm)[a]	Otolith mass (mg)[b]
Margaree	SFA 1	38	2.4 ± 0.1	12.4 ± 0.2	1.5 ± 0.1
Northwest Miramichi	SFA 16	29	2.3 ± 0.1	12.7 ± 0.2	1.6 ± 0.1
Southwest Miramichi	SFA 16	30	2.3 ± 0.1	12.4 ± 0.2	1.5 ± 0.1

[a] Fork length based on measurements taken from frozen-thawed fish.
[b] Otolith mass is the calcium-referenced mass used for elemental analysis.

Otolith preparation – Sagittal otoliths were removed, cleaned, and prepared for elemental analysis using a modification of the decontamination protocol described in Campana *et al.* (2000). All otoliths were handled with only high-density plastic materials (polyethylene and polypropylene), and all were pre-cleaned with trace-metal grade reagents. All steps to clean, then protect otoliths from potential contaminants were performed under a laminar flow, positive pressure fume hood lined with polyethylene sheeting that had been previously

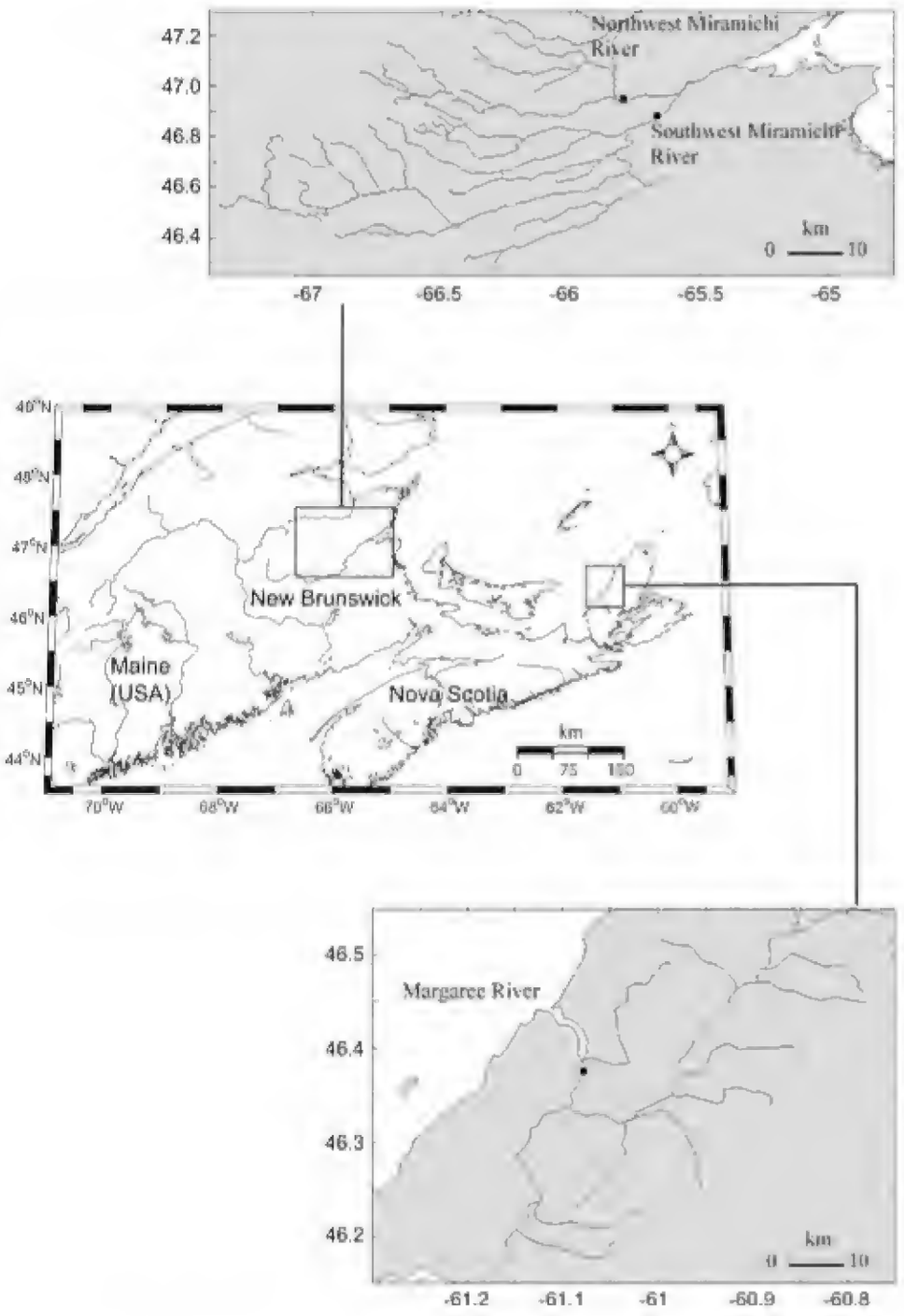

Fig 1 **Map of the watersheds in the Canadian Maritimes examined in this study, showing Atlantic salmon smolt collection sites (•).**

cleaned with 95% non-denatured ethanol, although 18 MΩ doubly deionized water ($DDIH_2O$) was used rather than Super Q water. Disposable polyethylene gloves were worn at all times when handling equipment and specimens and exchanged regularly.

Smolts were thawed in the laboratory for 3 h prior to dissection and examined for adipose fin clips that indicate hatchery origin. No smolts had fin clips. Fork length, to the nearest 0.1 cm, was recorded for each individual (Table 1). Sagittal otolith pairs were removed from all fish with acid-washed forceps, placed in acid-washed polypropylene caps, submersed in $DDIH_2O$, and any remaining biological tissue removed with fine tipped non-metallic, acid-washed forceps under a dissecting microscope. Right otoliths were used for age analysis and were air dried for 24 h before storage in acid-washed 2 ml polyethylene micro-centrifuge tubes. Left otoliths were used for elemental analysis and were placed in acid-washed 50 ml polypropylene vials for further cleaning which included immersion in $DDIH_2O$ and sonification for 5 min, triple rinsing in $DDIH_2O$, a 5 min soaking in ultra-pure 3% hydrogen peroxide, another 5 min sonification in $DDIH_2O$, followed by a triple rinse in $DDIH_2O$. Left otoliths were then placed in acid-washed polypropylene caps and air dried under the laminar flow, positive pressure fume hood for 24 h. Once dried, each otolith was weighed to the nearest 0.1 mg (Table 1). To remove any potential surface contamination from the weighing process, otoliths were triple-rinsed in $DDIH_2O$ and air-dried under the laminar flow, positive pressure fume hood for a final 24 h. Decontaminated left otoliths were stored in labeled, capped, acid-washed 5 ml polypropylene vials to await elemental analysis.

Empty vials were also prepared for blank corrections and to calculate limits of detection (LOD) with the same decontamination procedure carried out on the left otoliths. All vials were sealed within acid-washed polyethylene bags and forwarded to the Research and Productivity Council Laboratory (RPC) in Fredericton where all elemental analyses were conducted. At the RPC, decontaminated left otoliths were digested into solution in the original acid-washed containers with high-purity nitric acid in preparation for elemental analysis. After the initial reaction subsided, the samples were warmed in an oven (80°C) for 15 min to complete sample dissolution. After cooling, samples were diluted to a final volume of 2 ml with deionized water.

Age analysis – Age was determined by counting annuli on polished thin sections of right otoliths. Otoliths were chosen for age

determination because fish were not stored individually after collection and scale fidelity was lost. Otoliths were mounted sulcus side up on glass micro-slides with cyanoacrylate glue and allowed to dry for 2 h then polished to the mid-plane with 12 μm and 3 μm adhesive-backed metallurgical aluminum oxide (Al_2O_3) lapping film attached to a smooth glass plate. To enhance annuli visibility, otoliths were further polished with 0.3 μm lapping film. Because otoliths were small in size, only one side of the otolith required polishing to fully reveal annuli. The resulting otolith thin sections were then viewed under a compound microscope with transmitted light at 100x magnification and annuli were counted according to guidelines outlined by Chilton and Beamish (1982). Otoliths were aged on two separate occasions without previous knowledge of the specimens' estimated age or individual fork length. When the two age readings agreed, that age was assigned to the individual. When the two age readings disagreed, the ageing protocol was repeated until agreement. Self-comparison tests of otolith age estimates were conducted to measure within reader precision and age reproducibility (Campana *et al.* 1995a).

Elemental analysis – The use of solution-based assays was adopted to analyze the whole otoliths of smolts. The classification power of the elemental fingerprint is an important consideration for investigations involving lotic freshwater since the concentrations of some elements and isotopes in surface waters can often exhibit low spatial variability. Therefore, a suite of trace elements were analyzed as opposed to a single isotopic ratio. This multi-element fingerprint should maximize the observed differences between groups and increase classification accuracy.

All otolith sample solutions were analyzed by inductively coupled plasma mass spectrometry (ICP-MS) and inductively coupled plasma emission spectrometry (ICP-ES). With small sample sizes (mean sample size was ≈ 1.4 mg) greater analytical uncertainty for elements that are close to the detection limits was a concern, therefore, isotope dilution (ID) was not used since data improvement (increased accuracy, precision, and sensitivity) provided by ID would have been minimal (Campana *et al.* 1995b). In addition, simultaneous analysis by ICP-ES would have been made impossible since ID requires spikes of stable isotopes to be added to sample solutions. ICP-MS analysis was carried out using a Thermo X-7 ICP-MS instrument equipped with a high-pressure injection interface designed for high sensitivity.

The instrument was operated in a manual sampling mode to reduce analysis time and sample consumption. Indium (In) was used as an internal standard for ICP-MS analysis for all elements where µl of 40 µg/l ^{49}In was added to the final diluted volume of 2 ml for all samples after sample digestion in preparation for elemental analysis. Quantification was based upon external standardization. The only target element that was not assayed on ICP-MS was Fe, which is subject to molecular ion interferences in this instrument.

ICP-ES analysis was conducted using a Varian Vista Pro ICP-ES instrument. Quantification was by external standardization using matrix-matched standards. The solutions were manually sampled using a naturally aspirated micro-concentric nebulizer. Laboratory blanks, pooled otolith laboratory control material (LCM), and matrix-matched standards were analyzed concurrently with the samples at regular intervals throughout both the ICP-MS and ICP-ES analytical runs. Variability of the blanks indicated the ultimate detection limit for each element and the pooled otolith LCM provided a measure of within-run precision. Results from the matrix-matched standards and laboratory blanks were used for dynamic drift correction. Otolith samples were randomized across collection locations with respect to assay sequence to remove sample order bias. Finally, for most elements, multiple isotopes (ICP-MS) and multiple emission lines (ICP-ES) were used for analytical verification and to help detect potential molecular ion interferences.

A total of 27 elements were targeted for analysis by ICP-MS and ICP-ES. Based on preliminary analysis of element concentrations and element interferences significant data were obtained for 14 elements (Table 2). For elements analyzed by both methods and when multiple emission lines or isotopes yielded comparable data, preferred data sources were chosen on the basis of element sensitivity, known interferences, calibration stability, and background values (Table 2). Raw sample data were corrected for blank concentrations based upon the measured solution concentration factored with the average mass of all the samples. A proportional correction based upon the relative mass of the individual sample to the average otolith mass was used. For very small otoliths (<2.0 mg) Ca concentration is probably a more accurate determination of the actual amount of sample. Consequently, all reported element concentrations and subsequent data comparisons are based upon a sample mass normalized to a constant Ca concentration calculated from blank-corrected solution concentrations of Ca

Table 2 Limits of detection (LOD) and precision (CV) for significant elements in otoliths of Atlantic salmon smolts analyzed by ICP-MS and ICP-ES.

Instrument	Element	LOD[a] (µg/g)	CV[b] (%)	MAR[c] BCMC (µg/g)	NWM[d] BCMC (µg/g)	SWM[e] BCMC (µg/g)	BCMC> LOD (number of rivers)
ICP-MS	Ba	0.02	12.7	36.96	5.72	11.44	3
	Pb	0.0204	18.5	0.0201	0.0253	0.0255	2
	Li	0.004	5.0	0.020	0.053	0.056	3
	Mg	0.3	5.1	104.1	45.8	34.0	3
	Mn	0.02	3.5	5.07	8.91	13.29	3
	Rb	0.002	6.0	0.467	0.71	0.727	3
	Sr	0.04	9.0	898.07	622.34	996.01	3
	Tl	0.00006	7.9	0.04457	0.06052	0.04184	3
	U	0.00007	54.6	0.00102	0.00030	0.00027	3
	Zn	0.4	10.9	66.5	39.3	36.3	3
ICP-ES	B	0.6	13.2	0.3	0.5	0.5	0
	Ca	824	1.4	400000	400000	400000	3
	K	1	2.7	832	922	905	3
	Na	7	1.1	2974	2896	3052	3

[a] LOD based on nine laboratory blanks.
[b] CV based on seven pooled otolith laboratory control material.
[c] MAR BCMC represents blank corrected mean concentration within the Margaree River.
[d] NWM BCMC represents blank corrected mean concentration with the Northwest Miramichi River.
[e] SWM BCMC represents blank corrected mean concentration with the Southwest Miramichi River.

(Table 1).This approach corrects for weighing errors and produces accurate estimates of sample mass for all samples since the otolith is composed of nearly pure $CaCO_3$ (40% Ca by weight; Campana 1999). LOD for both ICP-MS and ICP-ES (LOD = 3 SD in µg/g of otolith mass) were below mean concentrations for all elements at each location,except for B and Pb (Table 2). Estimates of precision (coefficient of variation [CV = x SD/mean]) based on seven samples of pooled otolith LCM ranged from as low as 1.1% for Na to as high as 54.6% for U (Table 2). Since no strict criteria exist for retaining elements in these types of studies, Brazner *et al.* (2004b) recommended other studies involving otolith elemental fingerprints apply the following conditions: the blank corrected mean concentration for at least one sample site had to exceed the LOD, and the CV of replicate assays of standards had to be less than 30%. Upon applying these criteria to this study B and U were eliminated while Ba, Pb, Li, Mg, Mn, K, Rb, Na, Sr, Tl, and Zn were retained for statistical analyses. Calcium was

not included in subsequent analyses as it was only used as a sample weight reference to calculate concentrations of other elements.

Statistical analysis – Concentrations of individual elements in otoliths of smolts were grouped by collection and screened for normality of distribution (Shapiro-Wilk test) and homogeneity of variance (Bartlett's test). To normalize within group distributions of data, concentrations of Ba and Sr were cosine transformed, concentrations of Pb and Mn were log transformed, concentrations of Li and Tl were square root transformed, and concentrations of Mg, K, Na, and Zn were sine transformed. Concentrations of Rb were normally distributed but were log transformed to meet the assumption of equal variances across sample groups. Data points abnormally separated from the main data distributions with the potential to distort stock discrimination results were then removed. These included three Li values, two from the Margaree River data set and one from the Northwest Miramichi River data set.

Analyses of otolith elemental fingerprints were done using both univariate and multivariate analysis of variance (ANOVA). Differences between otolith elemental concentrations among individual watersheds were compared with a Bonferroni-corrected multiple comparison procedure. Elements significant in the univariate ANOVAs were entered into a multivariate analysis of variance (MANOVA) using Pillai's Trace as the test statistic as it is the most robust to violations of homogeneity and multivariate normality (Wilkinson *et al.* 1996).

Linear Discriminant Function Analysis (LDFA), using only those elements entered into the MANOVA, was employed to assess the ability of otolith elemental fingerprints to predict river of origin of individual Atlantic salmon smolts. A backward stepwise LDFA classification method tested the significance of the contribution of each variable (i.e., element) for discriminating across groups (i.e., rivers) using F-statistics, estimated by the discriminant analysis procedure. Backward stepwise LDFA enters all variables selected but retains only those elements with significant F-to-remove values (Wilks' Lambda, $P < 0.05$; Wilkinson *et al.* 1996). For comparative purposes, a forward variable entry approach was undertaken as well and no difference in classification accuracy or F-statistics was observed. Tolerance statistics were used to measure the correlation of elements used in the LDFA model. Tolerance values range from 0 to 1 with a low value indicating that the contribution of an element to the LDFA model is somewhat dependent on at least one other element (Wilkinson *et al.*

1996). A cross-validation algorithm (SYSTAT 2004), which uses a bias decreasing jackknife technique, was used to approximate stock discrimination accuracy of smolts from the three watersheds.

Discriminant analysis also aided in the graphical visualization of otolith elemental fingerprints in multivariate space. Scores for the first two canonical variates were calculated and plotted along with 95% confidence ellipses around the centroids of each group to illustrate significant multivariate differences in otolith elemental concentrations among rivers. All statistical analyses were carried out using SYSTAT software Version 11 (SYSTAT 2004).Data values are stated as mean ± SE unless otherwise indicated.

RESULTS

Age class ranges for Atlantic salmon smolts sampled from the Margaree River, the Northwest Miramichi River, and the Southwest Miramichi River were age 2 to age 4 (2.4 ± 0.1 yrs), age 2 to age 3 0.1 ± 2.2) yrs), and age 2 to age 0.1 ± 2.3) 3 yrs),respectively (Table 1). The age 2 smolt class dominated the Margaree River ($n = 23$), the Northwest Miramichi River ($n = 21$), and the Southwest Miramichi River ($n = 22$) samples. Only one age-4 fish was sampled and was from the Margaree River. There was 96% agreement from initial double readings of all otoliths with an average CV of 1.2%. Only four smolts required further age scrutiny with age differences between readings for those fish being one year.

Previous studies have documented fish age and size related differences in concentrations for some elements within the otolith, which can be confused for stock specific differences (Campana *et al.* 1995b, 2000). It was important to identify if such differences in samples among these management river stocks existed. ANOVA revealed no significant difference in length ($df = 2,94$, $P = 0.339$) or age ($df = 2,94$, $P = 0.348$) in fish collected from the watersheds (Table 1), but lengths may have been affected by storage protocols (Armstrong and Stewart 1997) and ages could not be validated (Campana 2001). Hence, otolith mass was used as a proxy for fish size and fish age (Campana *et al.* 1999). To internally verify this proxy, otolith mass (mg) was regressed separately on fish length (cm) and fish age (yr) – with one Margaree River outlier (stem and leaf plot; SYSTAT 2004). Least absolute deviations (LAD) regression using a modified version of the simplex

algorithm was selected to compute estimates of regression coefficients as it is robust to extreme observations present in the data set of the dependent variable and may provide better estimates of regression coefficients when outliers exist (SYSTAT 2004). Despite producing r^2 values which were low (0.169; Equation 1) and moderate (0.401; Equation 2), respectively, both relationships were significant ($df = 2, 94, F > 19.3, P < 0.001$) indicating that otolith mass reliably reflected the range of smolt lengths and ages observed (Fig 2). Fish length is ostensibly a function of otolith mass only as the constant spans zero.

Fish Length = 0.126 · otolith mass (± 0.029) - 0. (±0.357) (Equation 1)

Fish Age = 0.420 · otolith mass (± 0.053) + 0. (±0.126) (Equation 2)

Differences in otolith mass among watershed were not significant (ANOVA, $df = 2, 94, F = 0.558, P = 0.574$), suggesting that the relationships between elemental concentration and otolith mass (and by inference fish size and fish age) did not have an important influence.

Despite an insignificant relationship, an effect of otolith mass on concentrations of individual elements across groups and within groups was identified. A significant relationship was observed for only Sr and Tl with Sr concentrations negatively correlated with otolith mass across river stocks (ANCOVA, $df = 1, 95, F = 5.483, P = 0.021$) and Tl concentrations positively correlated with otolith mass within the Southwest Miramichi River (ANCOVA, df = 1, 28, $F = 5.269$, $P = 0.029$). Initially, concentrations of these elements were otolith mass detrended (Campana *et al.* 2000), but repeated statistical analyses performed without detrending element concentrations resulted in identical conclusions and an insignificant difference in otolith mass among samples was not expected to confound any stock-specific differences in otolith elemental concentrations. Thus, all results reported here are based on undetrended data.

Non-transformed mean (± SE) concentrations of the eleven elements retained for univariate and multivariate statistical analyses ranged from as high as 2 (± 34) µg/g for Na to as low as 0.0 (± 0.0036) µg/g for Pb, when examined across all rivers (Table 2). Most notably were the significant Zn concentrations in these samples (49.02 ± [3.25]; Table 2). When comparisons were made among river stocks, concentrations

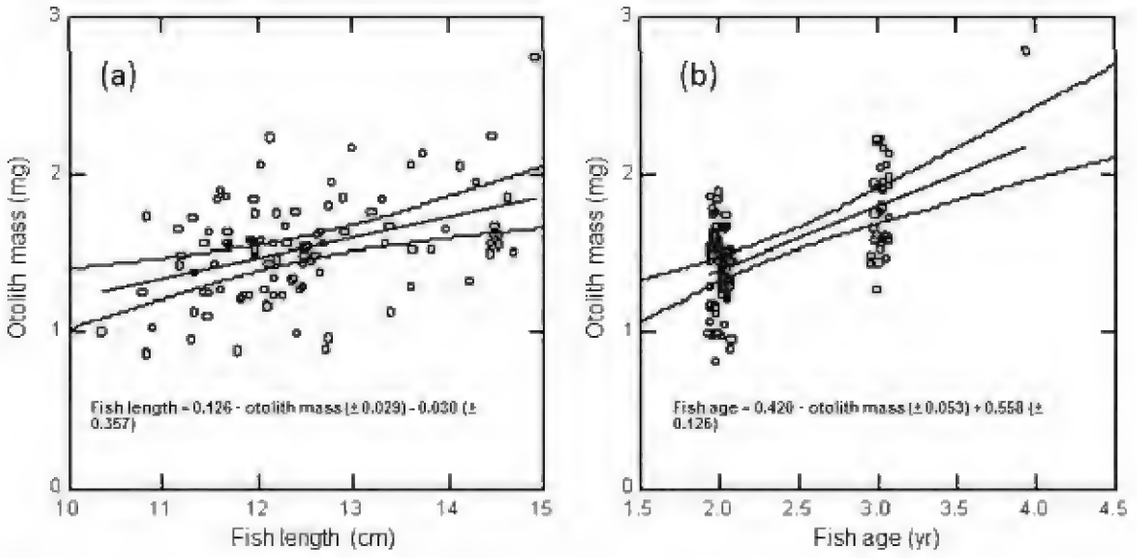
(a)
Otolith mass (mg)
Fish length = 0.126 * otolith mass (± 0.029) + 0.030 (± 0.357)
Fish length (cm)
(b)
Otolith mass (mg)
Fish age = 0.420 * otolith mass (± 0.053) + 0.558 (± 0.126)
Fish age (yr)

Fig 2 **Regression relationships between (a) otolith mass (mg) and fish length (cm) and (b) otolith mass (mg) and fish age (yr) for Atlantic salmon smolts sampled. Otolith mass (mg) is the calcium-referenced weight used for elemental analysis. Slight random jitter has been applied to the data due to overlapping points (SYSTAT 2004). Plotted above and below the regression lines are 95% confidence intervals.**

of Pb, Li, K, Rb, Na, and Tl in otolith samples from the Northwest Miramichi River were observed to be highest (6 of 11 elements) and four were alkali metals (Li, K, Rb, and Na; Table 2). Conversely, concentrations of Pb, Li, Mn, K, and Rb in Margaree River samples were lowest (5 of 11 elements) with the lowest concentrations overall measured in three of these five (Li, K, and Rb; Table 2).

Transformed mean concentrations for Ba, Pb, Li, Mn, Rb, and Tl (6 of 11 elements) differed significantly among watersheds (ANOVA, df = 2, 91, 94, $F > 4.133$, $P < 0.02$; Fig 3). Notable differences among river stocks were low Rb values for the Margaree River and high Tl values for the Northwest Miramichi River (Figs 3e and 3f). Mn was the only element that differed significantly among all three rivers (ANOVA, Bonferroni correction, df = 2, 94, $P < 0.029$; Fig 3d).

Concentrations of Pb were significantly different only between the Margaree River and Northwest Miramichi River (ANOVA, Bonferroni correction, df = 2, 94, $P = 0.04$; Fig 3b). Li and Rb differed significantly between both the Margaree River and Northwest Miramichi River (ANOVA, Bonferroni correction, df = 2, 91, 94, $P \leq 0.000$) and the Margaree River and Southwest Miramichi River (ANOVA Bonferroni correction, df = 2, 91, 94, $P \leq 0.000$; Figs 3c and 3e). The only elements to exhibit significantly different concentrations between the Northwest Miramichi River and the Southwest

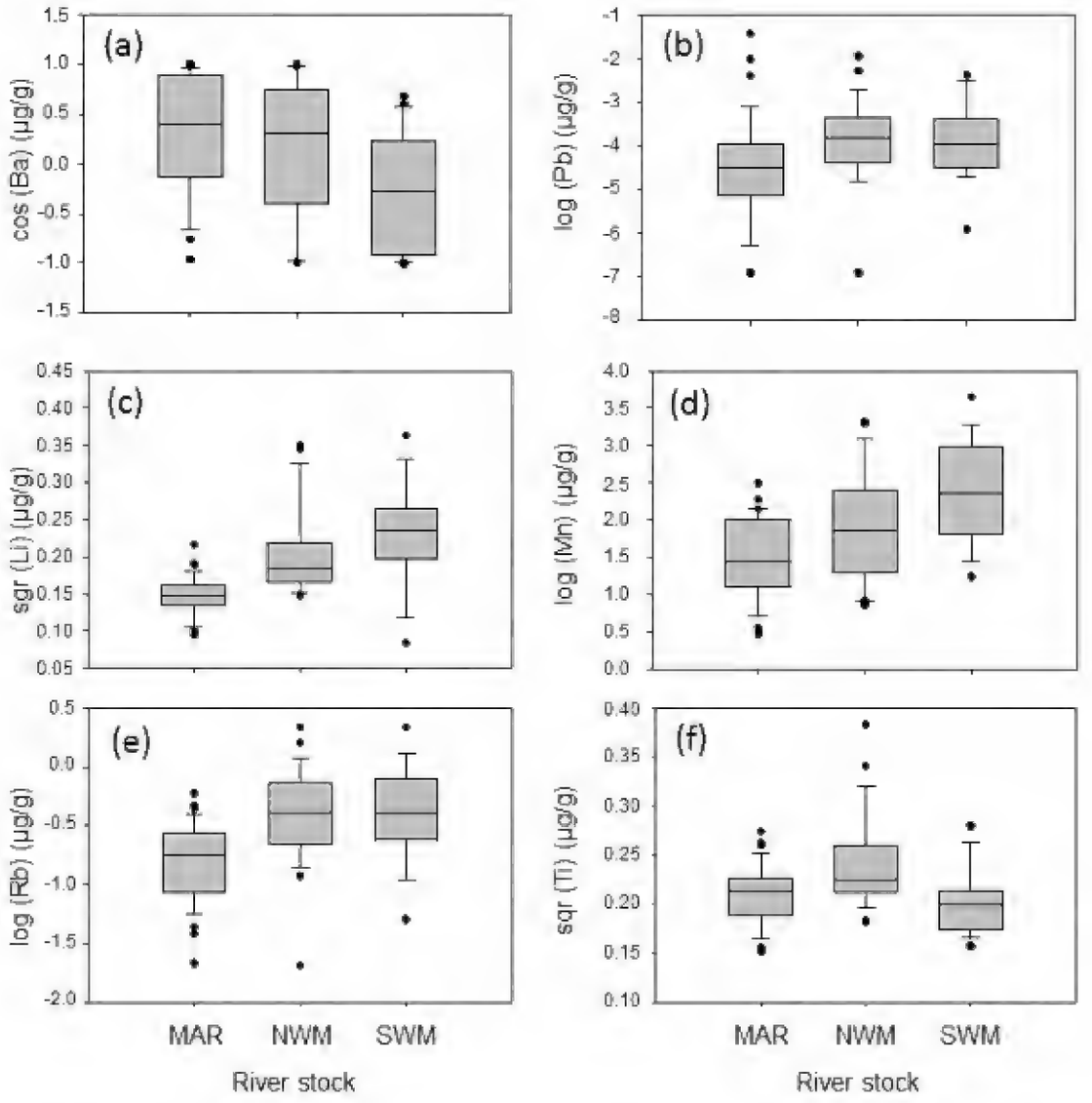

Fig 3 **Box plots of transformed (a) Ba concentrations (µg/g), (b) Pb concentrations (µg/g), (c) Li concentrations (µg/g), (d) Mn concentrations (µg/g), (e) Rb concentrations (µg/g), and (f) Tl concentrations (µg/g) in otoliths of Atlantic salmon smoltssampled from the Margaree River (MAR), Northwest Miramichi River (NWM), and Southwest Miramichi River (SWM).**

Miramichi River were Ba (ANOVA, Bonferroni correction, df = 2, 94, $P = 0.041$) and Tl (ANOVA, Bonferroni correction, df = 2, 94, $P \leq 0.000$; Figs 3a and 3f).

Omnibus river stock of origin differences were also observed when otolith elemental concentrations were analyzed as multivariate fingerprints (MANOVA, Pillai's trace, df = 12, 174, $F = 9.369$, $P \leq 0.000$). Concentrations of Pb differed significantly less among rivers when analyzed by MANOVA (Pillai's trace, df = 2, 91, $F = 3.813$, $P = 0.026$) than when analyzed by ANOVA (df = 2, 94, $F = 4.134$, $P = 0.019$).

Overall, MANOVA identified all six elements that differed significantly among rivers in univariate analyses as significant contributors

to by-river stock separation of elemental fingerprints in multivariate space, and this discrimination was even more distinct using a four-element (Li, Mn, Rb, and Tl) stepwise LDFA model (Wilk's lambda, $P \leq 0.000$). Ba and Pb were removed from the LDFA model because they were considered insignificant contributors to separation of the groups.

The first canonical variable (Factor 1) of the LDFA model captured the greatest amount of the difference among river management stocks (86%). Factor 1 best separated the Margaree River samples from the two Miramichi River groups. Canonical scores for Factor 1 were -1.332 (Margaree River), 0.195 (Northwest Miramichi River), and 1.416 (Southwest Miramichi River). Correlations between Factor 1 and individual elements were high for Mn (0.85) and Rb (0.84) and between the second canonical variable (Factor 2) and Tl (0.96). Based on high F-statistics, elements in the LDFA model in order of importance (first listed being of highest importance) were Mn (19.59), Rb (15.71), Tl (10.36), and Li (6.17; Table 3). Tolerance statistics for all four elements were greater than 0.64 (range 0.684 to 0.963; Table 3) indicating elements in the LDFA model were not highly correlated with other elements. Li had the highest degree of independence from other elements in its contribution to the LDFA model (Table 3).

Equality of group means examined using between groups F-ratio values revealed that measured group centroid distances were greatest between the Margaree River and the Southwest Miramichi and least between the Northwest Miramichi River and the Southwest Miramichi River. Distances between group means were also compared visually using a plot of the two canonical variables with 95% confidence ellipses centered on the centroid of each group (Fig 4). Canonical variable

Table 3 Summary of discriminant analysis (stepwise jackknife procedure) performed on elemental concentrations in otoliths of Atlantic salmon smolts sampled from three watersheds the Canadian Maritimes.

Element	F-statistic[a]	Tolerance[b]
Li	6.17	0.963
Mn	19.59	0.738
Rb	15.71	0.648
Tl	10.36	0.869

[a] F-statistic signifies importance of each element.
[b] Tolerance measures correlation of elements (0.00 = high correlation, 1.00 = low correlation).

scores for the Margaree River and the Southwest Miramichi River had less overlap relative to canonical scores for the Margaree River and the Northwest Miramichi River (Fig 4). Considerably more overlap existed for otolith elemental fingerprints between the two Miramichi River stocks. Spread of canonical scores for the Margaree River stock was low while distributions of canonical scores in discriminant space for both of the Miramichi River stocks were relatively wide in comparison (Fig 4).

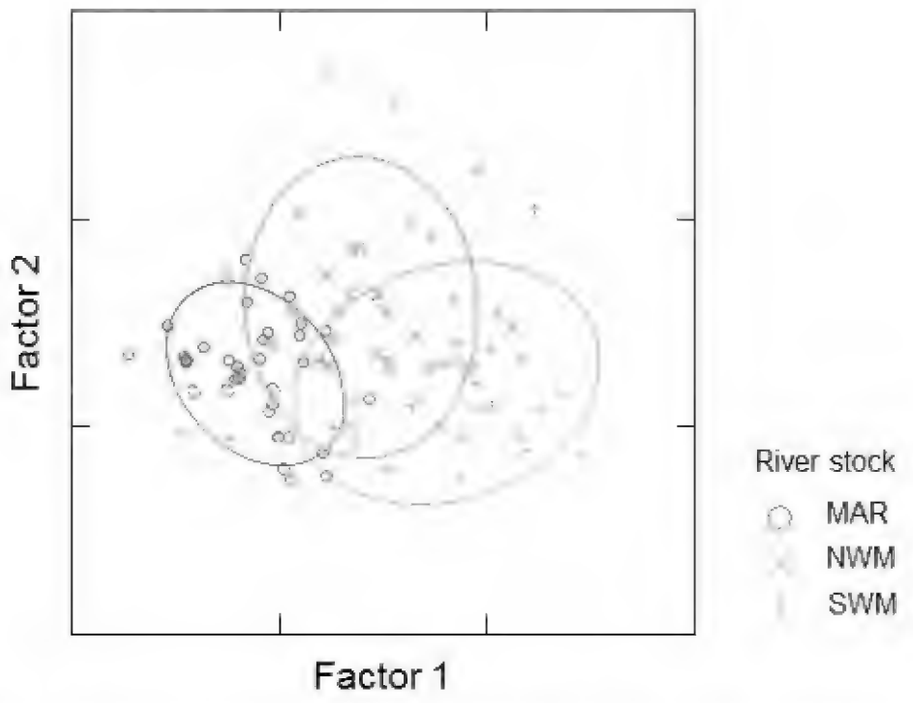

Fig 4 **Plot of canonical variable scores summarizing otolith elemental fingerprints of Atlantic salmon smolts sampled from the Margaree River (MAR), Northwest Miramichi River (NWM), and Southwest Miramichi River (SWM). Based on discriminant analysis of the four most significant predictor elements (Mn, Rb, Tl, and Li [ordered from most to least significant based on F-statistics]). Observations for each river illustrated with 95% confidence ellipses centered on group centroids.**

Overall classification success for the four-element stepwise LDFA model using a cross-validated jackknife classification technique was relatively high at 73%, with the highest accuracy for the Margaree River (92%) and lowest accuracy for the Northwest Miramichi River (46%; Table 4). The majority of fish misclassified from both the Northwest Miramichi River and the Southwest Miramichi River were classified as Margaree River fish whereas relatively few Margaree River fish were misclassified (3 of 36; Table 4).

Considerable overlapping distributions of scores in the canonical variable plot (Fig 4) and a relatively low *F*-ratio value between the

Table 4 **Classification matrix resulting from discriminant analysis (stepwise jackknife procedure) performed on elemental concentrations in otoliths of Atlantic salmon smolt sampled from three watersheds in the Canadian Maritimes. Results based on elements identified by discriminant analysis as significant predictor variables (Li, Mn, Rb, and Tl).**

	Predicted Watershed			
Actual Watershed	**MAR**	**NWM**	**SWM**	**% Correct**
Margaree	33	2	1	92
Northwest Miramichi	9	13	6	46
Southwest Miramichi	4	3	23	77
Total	46	18	30	73

Northwest Miramichi River and the Southwest Miramichi River suggested that otolith elemental fingerprints would be better discriminators at larger spatial scales where both Miramichi River stocks were components of a single group. To explore this hypothesis, samples were grouped according to major river system of origin and data were analyzed following the same elemental and statistical methods described for data grouped by management river stocks. An extremely high 92% mean cross-validated classification accuracy was achieved based on a significant (LDFA, Wilk's lambda, $P \leq 0.000$) four-element model that included Ba, Li, Mn, and Rb (Table 5). Classification accuracy was higher for the Miramichi River (93%) compared to the Margaree River (89%) with four fish from each river being misclassified (Table 5). Examination of F-statistics in LDFA revealed Ba was the most helpful variable in discriminating smolts from the two river systems followed by Rb, Li, and Mn (Table 6). Tolerance statistics indicated contributions of the four individual elements to group separation were highly independent (range 0. to 0.976; Table 6). These four elements along with Pb were also found to be significant contributors to separation among large river systems in multivariate space (MANOVA, Pillai's trace, df = 5, 90, $F = 35.943$, $P < 0.009$).

DISCUSSION

The variation in the elemental composition of whole otoliths of Atlantic salmon smolts was sufficient to discriminate among three watersheds in the Canadian Maritimes with 73% accuracy. Otolith elemental fingerprints when two watersheds were considered discriminated smolts with an accuracy of 92%. Mean classification accuracy

Table 5 **Classification matrix resulting from discriminant analysis (stepwise jackknife procedure) performed on elemental concentrations in otoliths of Atlantic salmon smolts sampled from two watersheds in the Canadian Maritimes. Results based on elements identified by discriminant analysis as significant predictor variables (Ba, Li, Mn, and Rb).**

Actual Watershed	Predicted Watershed		% Correct
	Margaree	Miramichi	
Margaree	33	4	89
Miramichi	4	55	93
Total	38	58	92

Table 6 **Summary of discriminant analysis (stepwise jackknife procedure) performed on elemental concentrations in otoliths of Atlantic salmon smolts sampled from two watersheds in the Canadian Maritimes.**

Element	F-statistic[a]	Tolerance[b]
Ba	41.05	0.976
Li	16.35	0.974
Mn	12.61	0.859
Rb	21.07	0.845

was lower when samples were grouped by river management stocks compared to when samples were grouped by large river systems partly due to the low classification rate (46%) of Northwest Miramichi River smolts. Some fish captured in the Northwest Miramichi could have been spawned in the Southwest Miramichi River and later dispersed into the Northwest branch during the latter portion of their freshwater residency. A more likely possibility is that smolts misclassified between the two Miramichi River branches by the LDFA is a reflection of the similar bedrock geology underlying the basins of both tributaries (Chiasson 1995). There were more cases, however, where fish collected from the Northwest Miramichi were incorrectly assigned to the Margaree River stock rather than the Southwest Miramichi stock. Quite probably there is substantial variability in the physicochemical character of the Northwest Miramichi watershed.

The most important variables for discriminating fish originating from the different watersheds were Ba, Rb, Li, and Mn, whereas the most significant predictors of river stock membership were Mn, Rb, Tl, and Li. In discriminating groups of fish in lotic and lentic freshwater systems, the best and most common explanatory variables have been Sr, Ba, Mn, and Mg (Thorrold *et al.* 1998; Wells *et al.* 2003a; Brazner *et al.* 2004a). Otolith concentrations of Sr and Mg were not

significantly different among watersheds, but both Mn and Ba contributed the greatest to group separation in the river management stock and large river system of origin LDFA models, respectively.

Observed differences in Ba concentrations probably reflect differences in Ba:Ca concentrations in the ambient waters of the three rivers at the time of deposition. Walther and Thorrold (2006) assessed the relative contributions of water and food sources to concentrations of Sr and Ba incorporated into the otoliths of a saltwater fish and found that almost all Ba (98%) deposited in the otolith aragonite was controlled by seawater chemistry. A correlation between water composition and uptake of Ba in the otoliths of freshwater fish has also been documented under both field and laboratory conditions (Wells *et al.* 2003a; Elsdon and Gillanders 2005), and variation in ambient Ba concentrations among and within freshwater environments was influenced primarily by the geology of the surrounding rock (Guay and Falkner 1998, Martin *et al.* 2013). Higher Ba:Ca concentrations in Margaree River otoliths, and presumably Margaree River water, than the Miramichi River, probably derive from the underlying geology of the Maritime Basin in eastern Canada (Kontak *et al.* 2006), particularly Ba-F mineral veins near the Lake Ainslie system within western Cape Breton Island (Kontak and Macdonald 1995).

Factors contributing to the observed variations in otolith Mn concentrations are not as clear. In his review, Campana (1999) presented evidence for an environmental effect on relative concentrations of Mn in freshwater and saltwater fish otoliths. Using new generation ICP-MS instruments, however, with the ability to quantify trace elements such as Mn with improved resolution, recent research has consistently revealed no correlation between water temperature, salinity, or ambient Mn abundance and otolith Mn:Ca ratios (Martin and Thorrold 2005; Hamer and Jenkins 2007), save for Dorval *et al.* (2005) who demonstrated a positive correlation between the Mn:Ca ratio in water and otolith.

Physiological processes are likely important to the incorporation of Mn:Ca ratios into otoliths based on obvious differences in otolith accretion rate (Hamer and Jenkins 2007) which is thought, in salmonids, to be coupled with factors related to metabolic rate (Wright 1991) including growth rate (Yamamoto *et al.* 1998), water temperature (Wright *et al.* 2001), oxygen concentration (Waller *et al.* 1997), and even life history strategy (Metcalfe *et al.* 1995). Mn is a highly regulated trace element (Bendell-Young and Harvey 1986)

essential for growth and metabolism in fishes (Lall 2002), which are two physiological parameters known to differ among stocks of Atlantic salmon with different geographic origins (Seppänen *et al.* 2009). Also, hydrological conditions varied among the watersheds across years when sampled smolts were rearing in natal freshwater habitats (DFO 1999, 2000, 2001b). Therefore, the observed significant differences in otolith Mn concentrations could be linked to physiology through the environmental availability of dissolved oxygen and ambient temperature.

Information on Rb, Li, and Tl is scarce. Concentrations of the alkali metal Li in fish otoliths and Rb in sea lamprey, *Petromyzon marinus* Linneaus, 1758, statoliths may reflect physical and chemical characteristics of the ambient environment (Campana *et al.* 2000; Brothers and Thresher 2004). Variations in otolith Li and Rb in relation to the proximity of specific rock types and mineral deposits (Friedrich and Halden 2008; Halden and Friedrich 2008) suggest the environment is the primary factor influencing the uptake of some of the alkali metals. Still, these relationships appear to be species-specific, indicating some physiological role in deposition (Chittaro *et al.* 2006). Li and Rb showed similarities across samples from different management stocks and freshwater systems suggesting local geology and ambient water chemistry were the principal factors influencing otolith concentrations of these elements.

Mean concentrations of Tl from the Northwest Miramichi River were elevated compared to mean concentrations for the Southwest Miramichi River and the Margaree River. It is possible that ambient concentrations of Tl in some areas of the Northwest Miramichi were high due to industrial sources during the time period of juvenile residency. Base metal mining operations have existed on a few tributaries of the Northwest Miramichi River since the 1960s and Tl normally occurs in discharged effluents from this industry (Zitko 1995). Arslan (2005) speculated that should variations in otolith Tl concentrations be detected it would be mainly due to differences in environmental availability of this element since the biological utility of Tl to the fish would be minimal and the affinity of the calcium carbonate otolith to Tl appears to be low. Stable isotopes of Pb and Se have also been detected in the otoliths of fish taken from aquatic environments significantly influenced by anthropogenic inputs (Spencer *et al.* 2000; Halden and Friedrich 2008).

Data on all environmental conditions for the time period of juvenile residence in natal rivers were not available to definitively support the premise that the ambient physicochemical environment primarily influenced otolith composition. A number of laboratory and field studies have documented a high correlation between otolith and water concentrations of some elements as influenced by temperature and salinity (Bath *et al.* 2000; Elsdon and Gillanders 2003b, 2004; Dorval *et al.* 2005) but it is unlikely that smolt size or age contributed significantly to differences in elemental fingerprints since there was no significant difference in smolt length, smolt age, or otolith mass of individuals collected among locations.

The successful application of otolith elemental fingerprints requires that three assumptions be met: (1) there are characteristic and reproducible markers for each group, (2) all possible groups contributing to the group mixture have been characterized, and (3) the marker remains stable over the interval between characterization and mixing (Campana 2005).Our elemental fingerprints appear to satisfy or display the potential to satisfy all three assumptions. One of the requirements of the first assumption has certainly already been met in that the fingerprints are characteristic markers of each of the rivers or area stocks examined.Also, they have already proven to be partly reproducible through the constancy of the smolt age and size ranges across stocks and river systems ensuring that elemental concentrations did not need to be detrended to remove any age or size effects (Campana *et al.* 2000).

Another aspect of reproducibility is the ability of the researcher to identify the correct growth increments to be sampled. Basing reference fingerprints on whole otoliths of smolts is advantageous since the smolt growth zone in otoliths of adult salmon is distinct (Kennedy *et al.* 2002) and can be used as a mark for where to initiate milling of the juvenile portion of the otolith for subsequent elemental analysis.

With regard to satisfying the second assumption, establishing sufficiently different otolith elemental fingerprints for all possible anadromous salmon river stocks contributing to themixed stocks in the North Atlantic Ocean is probably not practical considering there are more than 2100 individual rivers in North America and Europe with variable stock status (Crozier *et al.* 2004).Distinct elemental fingerprints for all possible groups at the meso-scale level of population organization (i.e., major river systems or biogeoclimatic zones) is a more realistic expectation.

The final assumption of marker stability between characterization and mixing is presumed met for elemental fingerprints based on analysis of the otolith core. Because of its metabolically inert nature, the composition of the otolith is not susceptible to resorption nor can it be reworked (Campana and Neilson 1985). Therefore, the otolith should maintain a permanent record of the physicochemical environment experienced by an individual during its lifetime (Campana 1999).

For Atlantic salmon, limiting elemental assays to the smolt portion of the otolith restricts the basis for the fingerprint to only elemental exposure and modification during an individual's freshwater life history. Concentrations of elements incorporated into the growing surface of the otolith from the time before hatch to the time of smoltification would then remain stable even after extended periods at sea and participation in multiple spawning events. The stability of the chemical composition of scales over the same interval is not as likely, especially after the juvenile period, maturation, and spawning (Wells *et al.* 2003b).

While stability in otolith core elemental composition is assumed, temporal persistence in otolith elemental fingerprints among multiple smolt year classes is not. Variation in elemental fingerprints between years was not assessed here, but some inter annual variability should be expected (Gillanders 2002).The magnitude of that variability would depend upon the chemical and physical dynamics of the aquatic environment (Elsdon and Gillanders 2006). Considering the range of sea-ages for Atlantic salmon, elemental concentrations would need to remain relatively stable over a 3-5 year period in order for reference fingerprints to be based on a single smolt year-class. While long-term (4-13 years) persistence is not commonly observed (Campana *et al.* 2000), combinations of some elements have maintained constancy in concentrations over shorter intervals of 2-5 years (Campana *et al.* 2000; Morris *et al.* 2003).

Another advantage of using otoliths is that they can be stored dry or frozen for long periods of time without loss of information. Because Atlantic salmon taken in many fisheries are processed immediately isolated recreational and commercial fisheries are difficult to sample for stock-specific characteristics unless scientific personnel are on hand (Tucker *et al.* 1999; Spares *et al.* 2007).Salmon heads are usually removed during processing and these can be frozen, hence preserving the otoliths for later study.

The results of our study demonstrate that otolith elemental fingerprints can be used to discriminate Atlantic salmon of different origins at an appropriate scale for studying population dynamics and managing stocks. Based on significant differences in the elemental composition of whole otoliths of smolts, mean classification accuracies were moderately high and extremely high for river management stocks and large river systems, respectively. Previous studies attempting to discriminate among stocks with the aid of natural marks have also achieved high classification rates, but not at the resolution needed to identify oceanic factors influencing differences in recruitment patterns which have been shown to act at regional scales (Friedland 1998; Friedland and Reddin 2000; Niemelä *et al.* 2004). More recent studies employing chemical marks have been able to discriminate among individual hatchery or stream populations (Flem *et al.* 2005; Veinott and Porter 2005; Martin *et al.* 2013), but may not meet the assumptions required to act as natural tags of origin for the purpose of ocean research and management. A metabolically stable natural tag of individual watersheds or large river system of origin would contribute considerably to research on marine factors that influence stick dynamics of Atlantic salmon.Such natural tags would also be useful to delineate and protect marine habitats critical for recruitment, estimating proportions of stocks subject to separate management regimes in mixed stock fisheries, and identifying salmon belonging to stocks which are not legally allowed to be exploited.

Conversely, the chemical and statistical analyses of smolt otoliths described in our study do show potential as a natural tag of large river system or biogeoclimatic zone of origin. Moreover, quantifying naturally occurring stable isotope ratios in otoliths (Kennedy *et al.* 2005) and analyzing the resultant isotopic signatures in concert with trace elemental fingerprints may increase classification accuracies further and satisfy the assumptions of mixed-stock analyses with even greater ease (Thorrold *et al.* 2001; Walther *et al.* 2008). First, however, future studies attempting to delineate the stock structure of Atlantic salmon in the marine environment should focus on further validating the use of smolt otolith elemental fingerprints as natural tags of large river system or biogeoclimatic area of origin. This may require cataloguing a library of otolith elemental fingerprints over time for each defined population unit (Gillanders 2002). Once accomplished, researchers should be able to characterize spatial and temporal meso-scale stock structure of ocean migrating salmon by analyzing otolith cores.

Depending on where research or fishing efforts are directed, the relative proportions of various stock groups utilizing known marine nurseries, staging areas, and feeding grounds (Reddin 1985; Reddin and Short 1991; Jacobsen *et al.* 2001) could be more accurately determined at a finer level of population organization. Considering recent research, which indicates trans-Atlantic migrations for North American salmon stocks (Spares *et al.* 2007; Dadswell *et al.* 2010; Soto *et al.* in review) and the endangered status of many river populations in adjacent regions, the development of empirical methods to accurately discriminate stocks in the North Atlantic Ocean at a scale appropriate for effective research and management is extremely important to the conservation and restoration of this species.

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Proceedings of the Nova Scotian Institute of Science (2015)
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NSIS COUNCIL

Reports from the Annual General Meeting, May 2014

1. Minutes of 152nd Annual General Meeting
2. President's Annual Report (Tom Rand)
3. Treasurer's Annual Report (Angelica Silva)
4. Editor's Annual Report (Peter Wells and David Richardson)
5. Librarian's Annual Report (Michelle Paon)
6. Webmaster Report (Suzuette Soomai)
7. Public Lectures
8. Student Science Writing Competition (Hank Bird)
9. Nominations for Positions on NSIS Council

MINUTES OF 152ND ANNUAL GENERAL MEETING

5 pm - 6 pm May 2013
The Great Hall, University Club
Dalhousie University, Halifax, NS

Council Members present: Michelle Paon (President and Librarian), Tom Rand (Vice-President), John Rutherford (Past President), Angelica Silva (Treasurer), Linda Marks (Secretary), Peter Wells (Editor), Henry Bird (Writing Contest Coordinator), Suzuette Soomai (Webmaster), Ron MacKay, Leigh Ann Bishop, John Young

Members present: Stuart Grossert, Jim Stewart, Michael Falk, David Richardson, Chris Corkett, Patrick Ryall, Timothy Lambert, Eric Mills, Ann Mills, Judy Bird, Carol Morrison, Sonia Gaul, David Richey, Matthew Richey

Regrets (Council Members): Allison Chua (Student Representative), Robert Boudreau (Mentorship Coordinator), Kevin Hewitt

The President welcomed members and called to order the 152nd Annual General Meeting. It was noted that the reports will be briefly summarized as all the reports have been made available to members with email prior to the meeting.

1. Approval of the Minutes of the 151st Annual General Meeting of 8th May, 2012

Motion to accept the minutes:
MOVED: John Rutherford
Seconded: Eric Mills
No discussion. All in favour. Carried

2. President's Annual Report (Michelle Paon):

Michelle Paon highlighted aspects of the President's Report.

A motion was passed at the 2012 Annual General Meeting requesting that the NSIS Council send a letter to Prime Minister Stephen Harper objecting to portions of Bill C-38. The motion was as follows:

"Council recommends that the Nova Scotian Institute of Science express to the federal government its concern regarding the degradation of environmental regulatory mechanisms, the proposed changes to the Fisheries Act, and the limits being placed on federally employed scientists to communicate the results of their research to the public."

A letter expressing the Institute's concerns was sent to the Prime Minister with copies sent to the federal Minister of the Environment and the Minister of Fisheries and Oceans, the leaders of the Opposition, Liberal and Green Parties, Opposition critics for the Environment and Fisheries, Speaker of the Senate, all Nova Scotia Members of Parliament, all NSIS members, and newspapers:The Globe and Mail and The Chronicle-Herald. Council felt that responses received from the Prime Minister's Office and from the Minister of Fisheries and Oceans Keith Ashfield left a number of questions unanswered and is therefore preparing a letter to Minister Ashfield.

The Institute had a very successful 2012-2013 lecture series with an average of 65 attending each presentation. In addition to the Institute's regular lectures the Institute co-sponsored two special lectures, one of which was organized to celebrate the NSIS 150th anniversary. Dr. Suzanne Zeller conducted research at the Nova Scotia Archives and reviewed the entire collection of the Proceedings of the NSIS to present a lecture entitled: "The Natural History of a Sustainable Institution: The Nova Scotian Institute of (Natural) Science since 1862".

In addition to collaborating with a variety of scholarly organizations and societies the Institute explored the links between science and music with Symphony Nova Scotia by working with the symphony to recruit scientists for pre-concert panel discussions which were held prior to the Symphony's performance of Haydn's Creation oratorio. The event celebrated the NSIS 150th anniversary.

Volume 47(1) of the Proceedings of the NSIS was published in December 2012. Michelle Paon thanked Editor Peter Wells, Associate Editor David Richardson, the editorial review board and Gail LeBlanc for their work and acknowledged the financial support of the Nova Scotia Department of Communities, Culture and Heritage.

Plans to transition to an electronic journal format are proceeding. The Institute has signed a "Memorandum of Understanding" with the Dalhousie University Libraries to publish the online version of the Proceedings. The Dalhousie University Libraries will host the journal by providing the server space and the electronic platform. The move to an electronic format will reduce the considerable costs involved in producing and distributing the Proceedings.

Michelle Paon thanked Henry Bird for coordinating a successful Student Science Writing Competition and acknowledged the financial support of Situating Science Strategic Knowledge Cluster. Awards

were presented in April prior to the monthly lecture. The Science Writing Competition is open to university students.

The NSIS also provided financial support to ten Science Fairs; the RobotsEast Atlantic Championship and to a graduate student poster competition at the annual conference of the Fishermen & Scientists Research Society.

Michelle Paon thanked webmaster Suzuette Soomai for her work maintaining the Institute's website and her present efforts coordinating a move of the site's contents to a new software platform. The redesigned website should be available in the fall of 2013.

Michelle Paon reported the passing of three long-standing NSIS members: Dr. Alan C. Grant; Past President Dr. Donald D. Betts; and Past President, Past Editor and Life Member Dr. Alan Taylor. On behalf of the Institute Michelle Paon extended condolences to the families and acknowledged the contributions made to the Institute by each scientist.

Michelle Paon thanked Council for its work and especially John Rutherford for his three years of leadership; Elaine McCulloch for staying on Council this past year to assist the new Treasurer; and retiring Nova Scotia Museum of Natural History observer David Christianson for all his contributions to the Institute.

Motion to accept the President's Report:
MOVED: Michelle Paon
Seconded: Ron MacKay
All in favour. Carried

3. Treasurer's Annual Report (Angelica Silva)

Angelica Silva presented the Treasurer's report which stated that as of the 31st March 2013 the Institute has a "net worth" of $54749.14. Expenses included publication of the Proceedings, promotion of the lectures, and prizes to the Writing Contest and the province-wide Science Fairs. The Treasurer noted that as of 31 March 2013 cheques issued to four of the Science Fairs had not been cashed. Revenue included the sale of the Proceedings, a payment from Access Copyright, and the 2011-2012 contribution from the Province of Nova Scotia in addition to the Province's 2012-2013 contribution. In May 2012 there was a transfer of $10,046.71 from savings to cover expenses.

The Institute currently has 98 individual members, including 8 life members and 2 student members. There are currently 20 institutional members.

John Young noted that Institute expenses have become higher in recent years.

David Richardson suggested that the term "Net Worth" be used instead of "Total Liabilities and Net Worth" on the first page of the Treasurer's Report and also noted that the Institute has fewer individual and institutional members than last year.

Motion to accept the Treasurer's Report:
MOVED: Angelica Silva
Seconded: Henry Bird
All in favour. Carried

Michelle Paon thanked Angelica Silva for taking on the challenging task as Treasurer. The Treasurer thanked Michelle Paon for all the "behind the scenes" work she performs on behalf of the Institute.

4. Editor's Annual Report
(Peter Wells /Associate Editor, D. Richardson)

Peter Wells presented the Editor's report: Volume 47 (Part1) of the Proceedings of the Nova Scotian Institute of Science (PNSIS) was published in December 2012. This issue continued with the new journal "look" which includes a colored cover and a new typeface.

The Editorial Board includes members from across the Province and has worked hard to attract papers and move them through the review process. The Editor thanked the Board for its work and enthusiasm.

To date several contributed papers are ready, or in the review process, for PNSIS Volume 47(2).

Progress has been made to make issues of the Proceedings available in both print and electronic formats (access through the NSIS website). Costs for producing and mailing print editions of the Proceedings are rising and, with the concurrence of members, the Proceedings will eventually become a digital issue.

Special issue, The Birds of Brier Island (PNSIS Vol. 46, Part 1, 2011), continues to sell and it is hoped that members will advertise this issue and help with its sales.

Peter Wells reported that ideas are being sought for future issues of the Proceedings. The Editor stressed that Institute members are welcomed to submit original papers, review papers, commentaries and editorials to the journal and noted that the Proceedings are a visible, written voice of the Institute.

Motion to accept the Editor's Report:
MOVED: Eric Mills
Seconded: John Young
All in favour. Carried

The President thanked Editor Peter Wells, Associate Editor David Richardson and production/layout editor Gail LeBlanc for all their work.

5. Librarian's Annual Report (Michelle Paon)

Michelle Paon reported highlights of the Librarian's report

Two additional volumes (Vol. 35, 1985 and Vol. 36, 1986) of the Proceedings have been digitized and deposited into DalSpace.

There are currently 20 Institutional Members (four less than last year). Renewal notices were sent to Institutional Members in January 2013 informing them of the increase in membership fees to $30.00. As of the 31 March 2013 renewals have been received for a total of $346.25. The NRC Institute for Marine Biosciences in Halifax cancelled its membership due to the closure of its library.

There are currently 89 Exchange Partners. As reported by Past Librarian Sharon Longard at the 2012 AGM a number of exchange partners (75 reported in May 2012 but due to a typographical error the number should be 85) were removed from the list because they had not sent publications to NSIS for two or more years.

Volume 47 (1) of the Proceedings was published in December 2012 and was mailed to all Institutional Members. To save on postage costs volume 47 (1) will be sent to the Exchange Partners following the publication of volume 47(2).

Sales of the Proceedings generated $1982.00 in revenue. The Flora of Nova Scotia continues to sell well. The Librarian thanked Eric Mills for helping to distribute and sell copies the Birds of Brier Island, which he authored.

The Institute received a 2012 repertoire payment to publishers from Access Copyright of $1870.13. This payment was much larger than normally received as it included a one-time payment (K-12 Tariff Special Dividend for Publishers) of $906.96.

Due to budget constraints the Killam Library will no longer bind print journal issues, including journals from the Institute's Exchange Partners. If journals show signs of wear selective binding will be carried out.

The Librarian acknowledged and thanked Carol Richardson and the staff of the Killam Library Serials Department who process the Institute's exchange journals and make them available at the Library.

Motion to accept the Librarian's Report:
MOVED: Michelle Paon
Seconded: Peter Wells
All in favour. Carried

6. Nominating Committee for 2013-2014 Report (John Rutherford)

Committee Chair John Rutherford presented the nominations for the 2013-2014 Council on behalf of the Committee which included Michelle Paon and John Young.

The Institute's by-laws states that "The officers, except the Librarian, shall be elected each year at the Annual General Meeting of the Institute and shall hold office until the next Annual General Meeting or until their successors are elected. The tenure of officers except the Librarian and the Editor, should not exceed five (5) years."

John Rutherford reported that the incumbent Secretary, Linda Marks, has been nominated for 2013-2014 although she has held the position for more than five years. The Nominating Committee felt that the by-laws did not preclude the opportunity to continue in the position as it did not state "must not exceed five years".

There were three calls for additional nominations from the floor. As there was "no contest" to the proposed slate of officers it was declared that the nominations be elected by acclimation.

New members to Council are Patrick Ryall, Vice-President and Jeff Gray, observer representing the Nova Scotia Museum.

Michelle Paon congratulated all members of Council and welcomed the Institute's new President, Tom Rand.

7. Lecture Programme for 2013-2014 (Tom Rand)

Lecture Committee Chair Tom Rand presented the lectures for 2013-2014 and thanked committee members Michelle Paon, Angelica Silva, Kevin Hewitt and John Young for their work.

The theme of the 2013-2014 lecture series will be energy. Ten speakers have been confirmed and two of the evening lectures will host dual-speaker events. Topics cover energy resources; the transformation of energy; and cosmic energy.

Michelle Paon thanked Tom Rand for his efforts.

8. Hall of Fame review (John Rutherford and Richard Singer)

John Rutherford reported that a suggestion was received in October 2012 that nominations to the Hall of Fame be opened to the public and that the criterion limiting eligibility to deceased individuals be dropped. Council discussed the implications of adopting these changes and referred the matter to a committee to present recommendations.

The committee's report summarized the Institute's current criteria used to evaluate a nominee for membership in the Hall of Fame. The criteria used by other organizations to recognize individuals were also reviewed.

Recommendations were made as follows:

1. That the current practice of nominating only deceased Nova Scotian scientists for Hall of Fame membership be continued. Including living individuals is not consistent with the intended purpose of the Hall of Fame.
2. That nominations for induction continue to be generated by members of Council, with the following provisos:
    a. That criteria for membership in the Hall of Fame be reviewed on a regular basis (e.g. every two or three years) by Council, or by a committee struck by Council, with an eye to determining whether new names should be added;
    b. That Council, or a committee struck by Council, be empowered to consult selectively with third parties (e.g. local historians of science, other organizations whose input is deemed to be useful and appropriate) of its own choosing to aid in its deliberations.
3. That, as a means of drawing public attention to scientists of note who are still actively engaged in research, the NSIS maintain on its website a list of the speakers who have contributed to the public lecture series over the past five (or ten?) years. Such a list would include the affiliations of each contributor, the title of the talk presented, and a brief description of the topic covered. Where possible, photographs of the speakers would be included.

It was noted that members could contact members of Council with their comments and recommendations.

Followings questions, John Rutherford briefly described the NSIS virtual Hall of Fame and the four major criteria currently used when evaluating an individual for inclusion:

- The nominee has made "significant" lifetime contributions to some field of science
- The nominee is Nova Scotian
- The nominee is deceased
- The nominee need not have pursued his or her scientific career in Nova Scotia.

Tim Lambert pointed out that not all recent Hall of Fame inductees are Nova Scotian born but were residents of the province, having spent a "substantial amount of their career in Nova Scotia".

John Rutherford stressed that every 2 – 3 years the policy could be reviewed. David Richardson noted that all nominations are discussed by Council prior to approval.

9. Other Business:

There was no other business.

John Rutherford expressed his gratitude to Council and outgoing President, Michelle Paon. Michelle Paon noted that she enjoyed her time as President.

10. Adjournment:

Moved: at 6:02 pm by David Richardson

Respectfully submitted,
Linda Marks
Secretary

REPORTS FROM THE NSIS COUNCIL NOVA SCOTIAN INSTITUTE OF SCIENCE

PRESIDENT'S REPORT: 2013 TO 2014

First and foremost, I want to take this opportunity to thank all Council members for their support during my tenure as President of the NSIS. It has been a fantastic year and I believe we have achieved many things. Secondly, I want to thank all of them for putting their faith in me as President. I have been honoured to serve the NSIS in this capacity and look forward to continuing work with the Institute in fulfilling its goals, especially in fostering and promoting Science in Nova Scotia and supporting the dissemination of peer-reviewed scientific research.

Public lectures: As all of you are aware, the NSIS has had a long history of inviting scientists to speak to the public about their research within the context of the NSIS monthly lecture series. The 2013 -2014 lecture year was organized by Michelle Paon, Kevin Hewitt, John Young and Tom Rand. The lectures were designed to focus on the general theme of ENERGY and were presented in three broad areas: energy sources, energy transformation, and finally world energy supply and the future of solar power. These lectures covered topics that ranged from the elegance of intracellular motors to the riddles of dark cosmic energy, from the diets of marine mammals to the detection of art forgeries. The lectures were attended by between some 30 people to 2 standing room only situations. The least number of attendees at the lectures was likely due to inclement winter weather. Based on my observations, all the lectures were well received and stimulated good questions and discussion at their conclusion.

The 2013-2014 lecture series comprised the following speakers and topics:

October 7, 2013 7:30 pm
NS Museum of Natural History
Dr. Mary Ann White: Department of Chemistry, Dalhousie University
Sustainable Approaches to Energy Harvesting and Storage

November 4, 2013 7:30 pm
NS Museum of Natural History
Dr. David Burton: Department of Environmental Sciences, Dalhousie University
The Nitrogen Problem

Dr. Jim Fawcett: Departments of Pharmacology and Surgery, Dalhousie University
Biological Nanomotors

December 2, 2013 7:30 pm
NS Museum of Natural History
Dr. Doug Staple: Department of Physics, Dalhousie University
World Energy Supply and the Future of Solar Power

January 6, 2014 7:30 pm
NS Museum of Natural History
Dr. Sara Iverson: Department of Biology, Dalhousie University
Energy Budgets in Marine Mammals: Tactics and Tricks

February 3, 2014 7:30 pm
NS Museum of Natural History
Dr. Christa Brosseau: Department of Chemistry, Saint Mary's University
Harvesting the Power of Light Energy – A New Tool for Art Conservation Science

March 3, 2014 7:30 pm
NS Museum of Natural History
Dr. Randall Martin: Department of Physics, Dalhousie University
Global Air Quality

Dr. Jason Clyburne: Department of Chemistry, Saint Mary's University
Carbon Dioxide: Capture, Uses, and Challenges

April 7, 2014 7:30 pm
NS Museum of Natural History
Dr. Rob Thacker: Department of Astronomy and Physics, Saint Mary's University
Dark Energy in the Cosmos

May 5, 2014 7:30 pm
Great hall, University Club, Dalhousie University
Dr. Louise Edwards: Department of Astronomy, Yale University
The Formation and Evolution of Galaxies

I would like to take this opportunity to publicly thank all of the speakers for their time, energy and commitment to helping support the NSIS lecture year with excellent presentations on their work. I also would like to thank members of the Nova Scotia Museum of Natural History, especially Jeff Gray and Robin Gilliam, for their help in enabling the NSIS to use their conference room and auditorium for hosting our monthly Council meetings and public lecture series.

Sponsorships:

1) ***Lectures:*** In addition to supporting the lecture year, the NSIS co-sponsored several conferences and meetings. On October 3, 2013, the NSIS, together with Situating Science National Strategic Knowledge Cluster, the Evolution Studies Group and Dalhousie University's College of Sustainability, amongst others, supported a public lecture by Dr. Philip Kitcher, the John Dewey Professor of Philosophy, at Columbia University entitled "CAN WE SUSTAIN DEMOCRACY, AND THE PLANET TOO?" The lecture was held in the Ondaatje Hall, McCain Building, Dalhousie University and attended at capacity by over 500 people.

Sable Island Group: The Ninth Annual Public Sable Island workshop was held on November 26 and supported in part by the NSIS. It was held at Saint Mary's University, attended by some 200 people, and chaired by myself.

Huntsman Award Lecture: On November 27, the NSIS supported the public lecture, "A Changing Sea" by Dr. Scott Doney, from the Woods Hole Oceanographic Institute and this year's Huntsman Award winner. The lecture was held in the Ondaatje Hall, McCain Building, Dalhousie University and attended by over 130 people.

Maury Conference on the History of Oceanography: The NSIS has provided both financial and organizational support for this Conference, which is scheduled for June 2014. In part, it is to honour the life and work of the eminent oceanographer, Dr. Eric Mills.

2) ***Student Science Writing Competition:*** The NSIS sponsored the Student Science Writing Competition, which was organized and overseen by Hank Bird whom we thank for his diligence in coordinating this wonderful initiative. The NSIS also acknowledges the Situating Science Strategic Knowledge Cluster-Atlantic Node, which also provided financial support for the competition. The writing contest is open to all Nova Scotian University science students.

Our congratulations go to the winners, two of whom were present at the April meeting of the NSIS. Prizes and certificates were awarded to the following:

In the undergraduate category, Honourable Mentions were awarded to Kaitlin Baur, Mount Saint Vincent University, for her paper on "Aesthetic Experience" and to Kerry McInnes, Dalhousie University, for her paper on "Mild Traumatic Brain Injury". In the graduate category the winner was Michael Butler, Dalhousie University, for his paper on "Post-Intubation Hypotension". An Honourable Mention was given to Penelope Kuhn, Saint Mary's University, for her paper on "Urban Agriculture".

3) ***Nova Scotia Regional Science Fairs:*** In addition to sponsoring the writing competition, NSIS continued to financially support 10 Nova Scotia Regional Science fairs in the form of $150.00 in prize money to each. NSIS also funded several other initiatives, including the graduate student poster competition at the annual conference of the Fishermen and Scientists Research Society in February 2014, and the RobotsEast Atlantic Championship for school children held in Halifax in May 2014.

On a sad note, a NSIS member, Dr. Robert G. Ackman passed away this year. Dr. Ackman was a long-time NSIS member, and President of the NSIS from 1973 to 1974. He also served as a member of the Editorial Board for the Proceedings of the NSIS.

The Future: In my estimation, the future for the NSIS is bright

The NSIS is financially secure. NSIS bank assets are some $70K, as of April 2014. In part these are supported by a bequest of $15,000 made by the late Dr. Alan Taylor to the "Library of the Nova Scotian Institute of Science, Halifax, Nova Scotia to be used for maintenance and expansion". The cheque was received in August and remitted to the NSIS treasurer. Over the past year, Council members have discussed meaningful ways in which to use the funds and have sought and found approved legal opinion on its use: Suggested uses include:

Putting the funds towards covering costs associated with electronically posting the Institute's journal, the *Proceedings of the NSIS* to its membership; Dividing the funds into two parts: one half would be used for supporting the PNSIS; the remainder would be used to generate interest which would be used to buy some books of interest to NSIS members; and providing a small amount of the money to the Halifax Public Library (and in future, possibly libraries including schools throughout the province) for the purchase of books on science aimed at mature readers.

On April 8, 2014, NSIS was provided with $1000 by the Minster of Communities, Culture and Heritage, the Honourable Tony Ince, to support the continued publication of the Proceedings of the Nova Scotian Institute of Science.

Initiatives: As already mentioned, NSIS goals include the fostering and promoting of Science in Nova Scotia and supporting the dissemination of peer-reviewed scientific research. Over the past year, Council has held several discussions on the state of Science in Canada. Amongst those discussions was the recognition that Federal scientists were being prevented from speaking with the media about their research. In response to this recognition, letters were sent to the Honourable Keith Ashfield (past minister) and to Gale Shea (current), Federal Ministers of Fisheries and Oceans, outlining our grave concerns about limits being placed on federally employed scientists to communicate the results of their research. NSIS also urged the Minister to encourage DFO scientists to speak freely about their research. In a brief response, the Minister stated that the public`s concerns about the `muzzling` of government scientists were essentially unfounded.

Council also discussed and identified meaningful ways in which NSIS can support Peter Wells' editorial call for supporting basic science in the region and encouraging evidence-based public policy on issues impacting on science in Canada (Editorial PNSIS. Vol. 47(2) 2013). In November 2013, Ron MacKay and I attended a public meeting at the Art Gallery of Nova Scotia. The meeting comprised a moderated panel of four discussing Science in the Public Interest, with approximately 60 people in attendance. It was an interesting meeting with a topic that not only sparked much emotion but provided insight into some of various strategies that could be employed to promote science in the region. In February 2014, a committee (John Young, Kevin Hewitt, Pat Ryall, Tom Rand and Kara McPhee), was struck, met and

discussed ways to increase NSIS membership and its involvement in promoting science in the region. In brief, ways identified included, amongst others: continued representation at and sponsorship of various public science-based conferences, meetings, open houses, and lectures; continued support of Nova Scotia Science fairs, the RobotsEAST competition, Checkmate, and the Fishermen and Scientists Research Society; through a NSIS Publicity Officer; Outreach (e.g. NSIS excursions; NSIS representation at Atlantic Science Teachers retreats); holding a NSIS membership card that confers membership benefits (e.g. free or discounted admittance fees at other Halifax or Nova Scotian museums, etc.) and; membership dues collected using swipe and or visa card payments. As of this writing, not all of these items have come to fruition but work is progressing and I hope to prepare a white paper that I expect to complete by the fall 2014.

In closing, I would like to again thank all members of Council for their commitment to the Institute, their support for its initiatives and the time they so generously give to the Institute in order to help it to achieve its goals. I extend a very special thanks to Michelle Paon for her incredible leadership help over the past year and for assisting me in learning the ropes. Two councillors will be retiring from Council this spring: First let me acknowledge the contributions of Linda Marks who will be leaving Council. Linda has served on the Executive since 2003 as a sitting member and as Secretary. We thank Linda for her indefatigable and conscientious efforts in keeping accurate minutes and her assistance and sound advice. Another experienced member, Allison Chua, student representative, will be leaving Council. Our thanks go to Allison for her thoughtful discussions and help, especially with the RobotsEAST competitions. Without the help, guidance and efforts of all of our members I would have found myself like a boat without a rudder.

As final comments, I think that the NSIS is a fabulous, well-recognised scientific organization. However, I do not think that we should rest on our laurels and the status quo. While interest in Science is alive and well in our province, I believe we should strive and continue to move forward by reaching out and appealing to the younger generation through school visits, science fair judging, etc., by increasing membership, by issuing membership cards that confer advantages to the card holders, for example, in providing them with discounted entrance fees to other pay-as-you-go organizations in Halifax, and

the wider NS community. There is also so much we can do outside our lecture sponsorships and lecture series to promote science in Nova Scotia. There is a very large science community in NS which we should try to tap into it. I look forward to continued engagement with the NSIS members and the public in the coming years to meet the goals of the Institute.

Thank you all for your support.

Respectfully submitted,
Tom Rand, President

TREASURER'S REPORT

NOVA SCOTIAN INSTITUTE OF SCIENCE

March 31, 2014

ASSETS:		
Bank Account BMO (March 31, 2014)	8,747.72	
Investments	60,381.52	
TOTAL ASSETS		**69,129.24**
LIABILITIES AND NET WORTH		
Accounts Payable		
NET WORTH		
TOTAL LIABILITIES AND NET WORTH		**69,129.24**
INVESTMENTS:		
Renaissance High Interest Savings Account (February 28, 2014) @ 1.0%		23,867.02
Manulife Bank Investment Certificate @2.45 % due February 1, 2018		21,000.00
Equitable Trust Company GTD investment @2.15% due May 16, 2017		5,000.00
Montreal Trust Co. Cert @3.25% due July 15, 2014		10,000.00
Interest – cash and cash equivalent		514.50
TOTAL INVESTMENTS (AS OF MARCH 31, 2014)		**$ 60,381.52**

REVENUES AND EXPENDITURES
for 2013-2014– Nova Scotian Institute of Science

REVENUE		
Membership Dues		
Individuals and institutions	4,087.00	
AGM (2013) (May 2013)	1,136.00	
Dr. Alan Taylor bequest		
(September 2015)	15,000.00	
Sales Proceedings, Birds	665.00	
Income/Royalties		
Access copyright Royalty	803.56	
Bank Interest	1.10	
TOTAL REVENUE		**$21,692.66**
EXPENSES		
Advertisement		
(lecture posters, pamphlets)	297.87	
AGM (2013)	1,286.39	
Supplies office	85.51	
Web site annual fee	70.00	
Web site Honorarium (M. Reed)	1,000.00	
Rent		
(Monthly lectures at MNHNS)	206.50	
Postage	190.65	
Donation/Prizes	2,450.00	
Proceedings Costs	3,000.55	
Transfer to short term		
investment **(Dr. A. Taylor)	15,000.00	
TOTAL EXPENSES		**$23,587.47**
Expenses over income 2013-2014		**$ 1,894.78**

Finances

The net worth of NSIS is $69,129.24 as of March 31, 2014. For this 2013-2014 period, NSIS received a total of $803.56 from ACCESS copyright for publication royalties.

Total expenditures for contributions to special lectures, writing competition contest and prizes totalled $2,450. These included $250.00 for undergraduate student winner of 2013 NSIS writing competition; $1,200 for eight Regional Science Fairs (4 -2013; 4-2013, 6 did not cashed cheques before March 31, 2014); $500 towards Situation Science lecture, $250 towards Ecology Action Centre Sable Island lecture; $250 to student poster winners at Fishermen and Scientists Research Society.

Membership

The NSIS has 108 members and include 4 students, 9 Life members and 17 Institutional Members. Dues from Individual members amounted to $3,490 and $597 from institutional members. Other income includes sales of proceedings and special publications (Flora of Nova Scotia, Birds of Brier Island) for $665 and ACCESS copyright Royalty of $803.56.

A bequest from former NSIS Life member, Dr. Alan Taylor's estate of $15,000 was received by NSIS and will be used as a long term fund to contribute towards expansion of library and communication of Science in Nova Scotia including donations of Science books to Municipal libraries in Nova Scotia and other initiatives.

Respectfully submitted to the NSIS AGM 2013-2014
Angelica Silva, Treasurer
Halifax, Nova Scotia
May 5th, 2014

EDITOR'S REPORT

NSIS ANNUAL GENERAL MEETING
May 5th, 2014

PNSIS Volume 47 (2) 2013
The latest issue, PNSIS Volume 47(2), 2013, was published in January 2014. It has an editorial and 6 papers on a variety of topics (from NS plant ecology to new fish records), as well as the Council reports. It has been distributed to all members and participating institutions.

PNSIS Volume 48 (1) 2014
Two papers are being considered for the next issue of PNSIS (Volume 48(1), 2014). One is an invited paper by Dr. Suzanne Zeller of Wilfred Laurier University on the 150 year history of the NSIS. The winning submissions of the Writing Contest will also be considered for the Proceedings. Papers coming in are slow at this stage. For this issue, we especially need to solicit papers from our speakers, and from contacts and colleagues of the Editorial Board throughout the province.

PNSIS Volume 48 (2) 2014-15
A special issue on Bay of Fundy science is being planned, based on papers from the upcoming BoFEP (Bay of Fundy Ecosystem Partnership) Workshop at the Coastal Zone Canada Conference in June 2014.

Changes to the PNSIS
A revised Guide to Authors is being prepared to aid the preparation of papers for the Proceedings. This will reduce the time to prepare final versions of accepted papers in a rigorous and consistent (i.e., standard) format. As well, preparations are moving ahead to have the Proceedings in an electronic format on the website. It will be available to Members only for 6 months, after which it will be open access. The Editorial Board and Members of Council have assisted greatly with these changes.

Promotion of the Proceedings

At the upcoming Coastal Zone Canada Conference, we will have a display table to promote the Society and our publications. We plan to do the same at the Maury History of Marine Science Conference at the same time, and likely others. Further suggestions on enhancing the PNSIS, its role in the Society, and its continued contribution to Nova Scotian and Maritime science are always welcome.

In Appreciation

Many thanks are due to the authors and the Editorial Board for their contributions to the Society.

Respectfully submitted to the NSIS Council and Members,
Peter G. Wells, Dalhousie University, Editor.
David Richardson, Saint Mary's University, Associate Editor.
May 3rd, 2014

LIBRARIAN'S REPORT 2013/2014

Prepared for AGM May 5, 2014

During the year, it has been a pleasure to serve as the liaison between the Killam Memorial Library and the Nova Scotian Institute of Science. In this role, I oversee the receipt of journals from NSIS exchange partners around the world. I also work with staff members who will facilitate online access to the *Proceedings of the Nova Scotian Institute of Science*, the society's peer-reviewed journal.

Proceedings of the Nova Scotian Institute of Science

During the summer of 2013, the Killam Library's graduate student interns, Nicole Bloudoff, Keriann Dowling, and Samantha Fritz, completed the digitization work on volumes 37-41 of the *Proceedings*, and deposited the volumes into DalSpace. I am happy to report that the content from vol. 1 (1863) to vol. 41 (2001) is now available free online in the DalSpace repository: http://dalspace.library.dal.ca/handle/10222/11192

In addition, *Proceedings* layout editor Gail LeBlanc converted journal issues from the past decade (2002-present) to portable document format (pdf), and the interns proofread the final products. Library staff uploaded the pdf articles to the online software (Open Journal Systems) that will serve as the production platform for forthcoming issues of the journal. The website now provides online access to issues of the *Proceedings* from vol. 42 (2002) to vol. 47 (2013): http://ojs.library.dal.ca/nsis.

For the first six months after its publication, access to the most recent issue of the journal is available only to NSIS members. It can be accessed through the use of a username and password. These are issued by Carol Richardson (clrichar@dal.ca), a Killam Library staff member who works closely with the NSIS Librarian.

Institutional Members and Exchange Partners

Renewal notices were sent to institutional members in February 2014. There are currently 19 institutional members (one less than last year). There are 87 NSIS exchange partners (two less than last year).

Volume 47, part 2 of the *Proceedings* was published in December 2013 and made available in January 2014. In order to save on over-

seas postage, volume 47 (parts 1 and 2) are to be sent to exchange partner institutions in a single mailing. A letter has been included in the envelopes to institutional members and exchange partners notifying them that forthcoming issues of the journal will be available online and providing information that will allow them to access the most recent issue of the journal via username and password or their internet protocol (IP) address.

Sales of the *Proceedings of the Nova Scotian Institute of Science*

During 2013/2014, sales of volumes of the *Proceedings,* including the new issue (volume 47, part 2), generated $853.50 in revenue. Please see Appendix A (attached) for details. Of note, during the summer, ten copies of the *Flora of Nova Scotia* were sold, and during the year, eight copies of the *Birds of Brier Island* were sold.

Access Copyright

The NSIS Librarian submitted the required forms to Access Copyright for the 2013 repertoire payment to publishers. NSIS subsequently received a payment of $803.56.

NSIS Exchange Journal Collection

NSIS continues to receive journal issues from exchange partners around the world. As an example, from October 2013 to April 2014, seventy-nine journal issues were delivered to the Killam Library from the Institute's exchange partners. Subject areas range from botany and zoology to mathematics and geology, while the languages of publication include English, Dutch, French, German, Japanese, Portugese and Swedish. These items have been processed and added to the NSIS collection in the Killam Library. On behalf of NSIS, I would like to thank Carol Richardson and the Serials Department staff in the Killam Library who process the exchange journals and make them shelf-ready.

Respectfully submitted,
Michelle Paon
NSIS Librarian
May 5, 2014

Appendix A

Date	**Volume/ Issue of *Proceedings of the Nova Scotian Institute of Science***	**# Sold**	**Price ($)**	**Amount Received ($)**
May 9, 2013	v.42, pt. 1, 2002	1	$22.00 + $5.00 S/H	$27.00
July 10, 2013	Birds of Brier Island	1	$25.00	$25.00
August 13, 2013	Flora of Nova Scotia	10	$35.00	$350.00
September 16, 2013	Birds of Brier Island	1	25.00	$25.00
November 4, 2013	Birds of Brier Island	4	$25.00	$100.00
November 12, 2013	v.42 pt.1 2002	1	$22.00 + $10.00 S/H	$32.00
November 26, 2013	v.45 pt. 1, 2010	2	$9.00	$18.00
November 26, 2013	v.45 pt. 2, 2010	3	$10.00	$30.00
November 29, 2013	Flora of Nova Scotia	1	$35.00	$35.00
December 2, 2013	Birds of Brier Island	2	$20.00 (Special xmas price)	$40.00
February 21, 2014	Birds of Sable Island (v.31, pt.1)	1	$10.00	$10.00
April 4, 2014	v.47, pt.2	5	$10.00	$50.00
April 17, 2014	v.41:pt.4(2001) v.42:pt.1(2002) v.43:pt.2(2006) v.44:pt.1(2007) v.45:pt.1(2010) v.45:pt.2(2010) v.46:pt.1(2011) v.46:pt.2(2011)	8	(various prices) Total = $111.50	$111.50
Total		**40**		**$853.50**

REPORT OF THE WEBMASTER

Report on Work Completed in April 2014

Routine maintenance of the website was completed in April 2014.

Council members are invited to submit photographs of science in action in Nova Scotia for posting on the website. As summer is approaching, keep in mind photographs from field trips that can be used in the image slider on the website's Homepage. Photographs should be of a high quality resolution, at least 700KB, and should be submitted as a jpg file to the webmaster.

Review of Work Completed between May 2013 and April 2014

The NSIS website was redesigned by Mike Reid, Dalhousie University, and the website was monitored weekly to ensure that the pages containing the news and upcoming lectures were loading correctly. Posters for the monthly lecture were posted in advance of the upcoming lecture.

The annual subscription for the NSIS website and email account, hosted on a server run by the Chebucto Community Net (CCN) Society, is current until January 2015.

The NSIS Webmaster remained in contact with the web designer, Mike Reid, regarding advice on web statistics and general operations of the site.

Suzuette Soomai
NSIS Webmaster

PUBLIC LECTURES
2014-2015

People and the Earth

From the beginning, people have been affected by the Earth, and people have been changing the Earth. There are natural events such as earthquakes; and there are phenomena, such as sea-level rise, which are happening through a combination of natural and human causes. The gases that we emit change the climate with impacts on water, soil productivity and food. How can we change our behaviour to correct these problems which are largely caused by our increasing consumption and how we produce energy? How can we make well-informed decisions when support for the necessary research is being cut? Please join us for a new lecture season that will address these questions and more.

Date	Topic	Speaker
2014		
October 6	Near-Earth Asteroids/ Earthquakes	Alan Ruffman
November 3*	Sea-level Rise in Nova Scotia	John Shaw
December 1	Geologic mapping of the Arctic Ocean	David Mosher
2015		
January 5	Carbon-cycles in Permafrost Regions	Rachel Chang
February 2	Impact of Global Land-Cover Change on the Water Cycle	Shannon Sterling
March 2	Advances in Nuclear Energy	AECL
April 6	Government Cutbacks in Science	Tom Duck
May 4	Crops Responses to Multiple Components of Climate Change	Mirwais Qaderi

*To be held in The Irving Centre at Acadia University in Wolfville

STUDENT SCIENCE WRITING COMPETITION 2014

May 2014 - Report for AGM

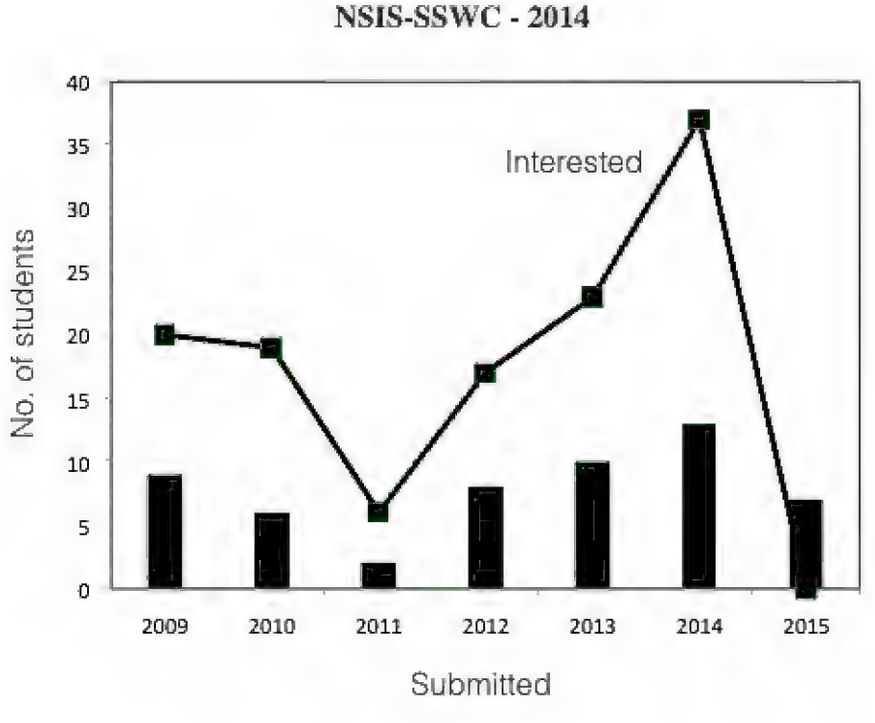
Thirty-seven students (21 undergrad., 16 grad.) expressed an intention to enter the 2014 Competition. By the deadline, thirteen of these students (4 undergrad., 9 grad.) submitted manuscripts.

This year, Hank Bird, Stuart Grossert, Tom Rand, David Richardson, John Rutherford, and Pat Ryall served as judges. Two Honourable Mentions were awarded in the undergraduate category, and in the graduate category one Hon. Ment. and one Prize were awarded.

Hank Bird
SSWC Coordinator

Univ.	Interest	Submitted
Acadia	4	0
CBU	3	1
Dalhousie	7	4
MSVU	0	0
StFX	1	1
SMU	1	1
Total =	**16**	**7**

Year	Interest	Submitted
2009	20	9
2010	19	6
2011	6	2
2012	17	8
2013	23	10
2014	37	13
2015	**16**	**7**



NSIS 2015 Student Science Writing Competiion

Undergraduate:

Name	University	Degree	Discipline	Paper Short Name
Sara Balish	Dalhousie	B.Sc.	Marine Biology (+ History)	Marine Mammals and Aquaculture
Rebecca Lavigne	Acadia	B.Sc.	Biology	(No Submission)
Hyun Woo (Sam) Jang	Dalhousie	B.Sc.	Medical Science	Oncolytic Reovirus
Kori Andrea	CBU	B.Sc.	Chemistry	Caolfield Mine Water
Gerry Petrash	Dalhousie	B.Sc.	Engineering	(Withdrew)
Elizabeth Jessome	CBU	B.A.	Philosophy/Biology	(Withdrew)
Katelyn Mansfield	Acadia	B.Sc.	Psychology (Neuroscience)	(Withdrew)
Rebecca Strachan	Acadia	B.Sc.	Biology/Chemistry	(No Submission)
Robert Lovell	CBU	B.Sc.	Biology	(No Submission)
Chelsea Cameron	StFX	B.Sc.	Nutrition	Haskap Berries

Graduate:

Name	University	Degree	Discipline	Paper Short Name
Lina Koronfel	Dalhousie	M.Sc./Ph.D.?	Medical Neuroscience	(No Submission)
Takafumi Osawa	Dalhousie	M.E.S.	Resource & Environmental Studies	Isthmus Biogeography
Kerry McInnes	Dalhousie	M.Sc.	Physiotherapy (Rehabilitation Research)	Motor Imagery
Christine Anderson	Acadia	M.Sc.	Biology	(No Submission)
Antonio Varga	Dalhousie	Ph.D.	Math & Statistics	(No Submission)
Fergus Tweedale	SMU	M.Sc.	Applied Science (Geology)	Mineralized Zones

NOMINATIONS TO POSITIONS ON NSIS COUNCIL 2014-2015

Officers

President:	Patrick Ryall
Vice-President:	Jason Clyburne *
Past President:	Tom Rand
Secretary:	Kelly Krashinsky *
Treasurer:	Angelica Silva
Editor:	Peter Wells
Librarian:	Michelle Paon
Webmaster:	Suzette Soomai
Publicity:	vacant

Councillors

Henry (Hank) Bird	(Writing Competition Coordinator)
Leigh Ann Bishop	(Science Teacher's Representative)
Kevin Hewitt	
Ron MacKay	
Rick Singer	
John Young	

Student Representative

Zoe Kirste *

Observers

Laura Bennet *	(Nova Scotia Museum)
Kara MacPhee	(Discovery Centre)

* New member on Council

Auditor

Michael Falk

BIO-Oceans Association announces the publication of a major treatise reviewing the history and marine research accomplishments at Canada's Bedford Institute of Oceanography over five decades primarily in the Atlantic and Arctic Oceans.

Voyage of Discovery

Fifty Years of Marine Research at Canada's Bedford Institute of Oceanography

Edited by D.N. Nettleship, D.C. Gordon, C.F.M. Lewis and M.P. Latremouille

A commemorative volume in celebration of the 50th Anniversary of BIO: 1962 - 2012

VOYAGE OF DISCOVERY summarizes BIO research results on the oceanography of Arctic and Eastern Canada. In a series of 48 papers by past and present research staff from all oceanographic disciplines at BIO, the history of Canadian oceanography before BIO and a broad cross section of the Institute's work spanning five decades are featured with particular emphasis on contributions to Canadian and global understanding/management of the marine environment.

Divided into 12 sections with a Preface and Epilogue, **VOYAGE OF DISCOVERY** is the most extensive overview of the history and scientific accomplishments of the Bedford Institute of Oceanography under one cover: Historical Roots, Arctic Studies, Ocean Life, Ocean Circulation and Chemistry, Hydrography and Seabed Mapping, Geological Oceanography, Fisheries-Ecosystems-Aquaculture, Marine Contamination, Technology and Instrument Development, Energy Developments, BIO and the Law of the Sea, and The BIO Experience. This book's well-written and illustrated accounts will appeal to a broad readership from professional oceanographers and environmental/resource managers and decision-makers to marine science students and lay persons interested in the Arctic and Atlantic oceans, and their present status and future welfare.

VOYAGE OF DISCOVERY

Hardcover, text on premium 8.5 x 11 inch glossy 100 lb Sterling paper with sewn binding
460 pages, 2.2 kg.
Price: $35.00 Cdn/US plus shipping
ISBN 978-0-9936443-0-6
BIO-OA Publication: October 2014

ORDER FORM

To order one or more copies of *Voyage of Discovery*, please complete order form below and send with payment (money order, cheque, credit card) or purchase order (for libraries, institutions, universities) to: **BIO-Oceans Association (VOD), c/o Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia, Canada B2Y 4A2.**

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With many thanks for your order from BIO-Oceans Association

INSTRUCTIONS TO AUTHORS

Papers may be submitted in either English or French and should be sent electronically to the Editor at (nsis@dal.ca and oceans2@ns.sympatico.ca). Submission of a manuscript will be taken to indicate that the work described is completely original, i.e., is the author's work and has not been published before, and is not being considered by another journal. All authors of a paper must approve of the submission prior to it being submitted. For review papers, authors wishing to include figures, tables, or text passages that have already been published elsewhere must obtain permission from the copyright owner(s) before the manuscript is submitted.

Authors are encouraged to submit illustrations and line drawings in colour.

Please refer to more recent issues of the Journal for general layout of papers. Pages of the electronic submission should be numbered. Authors may also include line numbers.

Please indicate running head of paper.

The title should be followed by names, addresses with e-mails of all authors. A footnote with an asterisk and worded: * Authors to whom correspondence should be addressed with the appropriate email address should be placed at the bottom of the first page of the manuscript.

An abstract of up to 200 words should follow. As appropriate, sections devoted to introduction, methods, results, discussion, conclusions and references should be included. Canadian spelling and SI units should be used wherever possible.

Latin or *scientific* names should be in italics as well as abbreviations like *et al.*

There should be a list of not more than five keywords after the abstract.

All tables, figures, photographs and illustrations should have a title and a self-explanatory legend, sent in separate files at 300 dpi or higher. Not to be embedded in the working document but the authors may indicate where each might be placed in the manuscript.

References are to be in alphabetical order – name first, initials after, with no space between initials. Give full title of the journal and issue numbers where appropriate, thus:

Nielsen, K.J., & France, D.F. (1995). The influence of adult conspecifics and shore level on recruitment of the ribbed mussel *Geukensia demissa* (Dillwyn). *Journal of Experimental Marine Biology and Ecology* 188 (1):89-98.

Cushing, D. & Walsh, J. (1976). The Ecology of the Seas. W. B. Saunders Company, Toronto.

Lee, G.F. (1975). Role of hydrous metal oxides in the transport of heavy metals in the environment. In: Krenkel, P.A. (ed.), Heavy Metals in the Aquatic Environment. Pergamon Press, Oxford, pp. 137-147.

Personal Communication: Smith A.J. (2001, pers. comm.) in text.

Website Citation: Author (year) title, URL and date accessed.

Authors are responsible for correcting and electronically returning proofs promptly. Authors will be provided with a PDF of their paper, free of charge. NSIS members are able to access the Proceedings as soon as published as part of their annual membership. All new issues become open access after a six months embargo. A limited number of each issue will continue to be printed for members and other interested parties. Copies of any Special Issues of the NSIS proceedings published in hard copy may also be purchased from NSIS at a charge established by the NSIS. See the NSIS website http://nsis.chebucto.org/ for details.

RECOMMANDATIONS AUX AUTEURS

Les auteurs peuvent soumettre leur manuscrit en anglais ou en français et doivent l'envoyer au rédacteur en chef par courriel (nsis@dal.ca et oceans2@ns.sympatico.ca). La soumission d'un manuscrit indiquera que les recherches décrites sont tout à fait originaux, c.-à-d. c'est le travail de l'auteur et n'a pas été publié avant, et n'est pas envisagé par une autre revue. Tous les auteurs d'un manuscrit doivent donner leur approbation avant de le soumettre. Pour les articles de synthèse, les auteurs qui désirent inclure des figures, des tableaux, ou des parties de texte déjà publiées ailleurs doivent obtenir la permission du (des) titulaire(s) de ces droits d'auteur, avant que le manuscrit soit soumis.

Les auteurs sont priés de soumettre en couleur les illustrations et les dessins au trait.

Veuillez consulter un récent numéro du Journal pour vérifier les exigences en matière de presentation. Les pages soumises par voie électronique doivent être numérotées. Les auteurs peuvent également numéroter les lignes de texte.

Veuillez indiquer le titre courant du manuscrit.

Le titre du manuscrit doit être suivi des noms de tous les auteurs, leurs adresses respectives et leurs adresses de courriel. Une note infrapaginale précédée d'un astérisque (*Auteurs correspondants:) doit figurer au bas de la première page du manuscrit et doit etre suivie des adresses de courriel des auteurs correspondants.

Un résumé doit suivre qui comptera au plus 200 mots. Si approprié, il doit y avoir des sections tel que l'introduction, les méthodes, les résultats, la discussion, les conclusions et les références bibliographiques. Il est recommandé de se servir de l'orthographe canadienne-française et du Système international d'unités.

Les noms *latins* ou les noms *scientifiques*, ainsi que les abréviations (par exemple: *et al.*) doivent être écrits en italique.

Une liste de mots clés (contenant pas plus de cinq) doit suivre le résumé.

Chaque tableau, figure, photographie ou illustration doit porter un titre et une légende *auto-explicative* et doit être envoyé par fichier électronique de 300 ppp ou plus. Par explication hors du texte, les auteurs peuvent indiquer où chacune des images doit être située dans la mise en page.

Les références bibliographiques doivent être en ordre alphabétique – nom de famille, suivi des initiales des prénoms (pas d'espaces entre les initiales). Indiquez le nom complet de la revue, et si approprié, les numéros des revues, comme les exemples suivants:

Nielsen, K.J., & France, D.F. (1995) The influence of adult conspecifics and shore level on recruitment of the ribbed mussel *Geukensia demissa* (Dillwyn). *Journal of Experimental Marine Biology and Ecology* 188 (1):89-98.

Cushing, D. & Walsh, J. (1976) The Ecology of the Seas. W. B. Saunders Company, Toronto.

Lee, G.F. (1975) Role of hydrous metal oxides in the transport of heavy metals in the environment. In: Krenkel, P.A. (ed.), Heavy Metals in the Aquatic Environment. Pergamon Press, Oxford, pp. 137-147.

Communication personnelle: Smith A.J. (2001, pers. comm.) in text.

Document sur un site web: Auteur (l'année de publication) titre, URL et la date de consultation.

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